Energy and Environmental Management in Egypt
Bioenergy CDM projects for Sustainable Development

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ENERGY AND ENVIRONMENTAL MANAGEMENT IN EGYPT
BIOENERGY CDM PROJECTS FOR SUSTAINABLE DEVELOPMENT

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Abstract

In the rapidly developing economy of Egypt with the increasing population density and depleting natural resources, the management of energy and environment has become of utmost importance to the sustainability of our development. A clear example is the severe air pollution, which is causing the most environmental damage, being mostly attributed to the energy sector, and largely attributed to uncontrolled burning of solid waste and agriculture residue. It mainly affects Greater Cairo, which hosts 20% of the nation’s population. This comes at a time where Egypt is rapidly approaching energy dependency. Utilizing this “waste” as a resource, or fuel, for bioenergy systems would entail many environmental and developmental benefits. This research has aimed to investigate the status and prospects of developing this bioenergy industry, and to discuss the approach to assess its sustainable development impacts as Clean Development Mechanism Projects (CDM) encompassing the environmental, social, and economic aspects in the context of the related legal and institutional framework existing today, and stakeholders’ activities. The findings of the research are later elaborated in the context of a case study of biogasification demonstrational plants established in Egypt delivering town gas from rice straw, while discussing the positive and negative sustainable development impacts. The research findings showed promising prospects for a growing bioenergy industry in Egypt and thereby emphasized the importance of identifying such synergies in environmental planning and management such as in addressing air pollution and promoting rural development, and it also emphasized the importance of practicing a holistic approach for assessing projects, policies and programs related to energy and environment. Findings also revealed a lack of proactive hosting of CDM projects in practice to direct activities toward national development priorities and finding synergies given that the CDM has come to be the driving force for bioenergy projects in Egypt. From the international perspective, a stricter and regular monitoring of SDA practices in the host country is recommended.
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1. Introduction

As the population of Egypt continues to grow approaching 80 million citizens, and resources for energy and materials deplete, material and energy recovery become key to sustainable development. The main environmental problems in Egypt are most evident in its overpopulated cities. Greater Cairo (GC) is most affected. GC is the expanding urban agglomerate that has grown out of its original city limits, the capital Cairo. It has consumed the strip of fertile land along the Nile River and is today growing into the desert. GC is home to more than 15 million people today, making it the largest city in the Middle East and North Africa, and by far the oldest. The nuclei of this agglomerate range between ten years to thousands of years old, which is reflected in its relatively unplanned structure and diverse cultural heritage. Today, the public health, environment, economy, and cultural heritage of this mega city are all strongly affected by the severe impact of challenged environmental management and high population density, already affecting the quality of life of its inhabitants and threatening a healthy life for future generations.

Among the many concerns that specifically affect GC is the poor air quality directly affecting public health. Air pollution in GC peaks every year in the autumn season, creating the acute air pollution episode known as the black cloud period. There are several factors causing this problem, such as the emissions from the 3 million vehicles in the city, violations in industrial emission, and open burning of municipal and agricultural residue. Open burning of solid waste and agriculture residue alone have been estimated to account for 42% of annual air pollution (SOE 2005). Together with certain weather and meteorological conditions, the air pollution reaches severe levels in that period.

Today, one of the main anthropogenic causes of the Black Cloud phenomenon is suspected to be the uncontrolled open-burning of rice straw. Yet difficulties in management and lack of incentives have hampered the efforts to address this problem. However, rice straw can in many ways become a valuable product if proper methods for material and energy recovery are followed, such as recycling or using biomass technology for generating heat and electricity. Therefore, prospects for increased use of bioenergy may promise better environmental conditions in Egypt, while reducing GHG emissions. Furthermore, on a strategic planning level, introducing bioenergy technology in Egypt will create valuable opportunities for further savings on energy and material otherwise wasted, since even municipal solid wastes are mainly consisting of organic material. Moreover, this type of industry is likely to be labour intensive for the collection and handling of biomass, therefore likely to enhance socio-economic development. The realization of this potential synergy between benefits in energy, local and global environment, socio-economic development and other aspects of sustainable development, was the motivation of this research.

1.1. Aim

The aim of this research is to emphasize the role of bioenergy technology in Egypt for sustainable development and environmental sustainability.
1.2. **Objectives**

The objectives of this research are as follows:

- To investigate the potential sustainable development impacts of bioenergy promotion in Egypt, both positive and negative.
- To investigate the status and prospects for bioenergy promotion in Egypt.
- Conduct a case study of an emerging bioenergy system in Egypt to elaborate on the research findings, and to discuss the indicators of SD in potential CDM - projects.

2. **Methodology**

This research was conducted based on reviewing the existing related literature, in addition to interviews with stakeholders, policy makers, and field visits. The research was conducted on the current practices related to sustainable development assessment in Egypt and related regulations, the status of the bioenergy industry in Egypt in different aspects, and the relation to sustainable development. This relation was then emphasized through a study of the relation of biomass to one of the most critical environmental problems in Greater Cairo, air pollution, in addition to other problems. Finally, a case study of a newly introduced bioenergy technology in Egypt is investigated in order to elaborate on the practical aspects of promoting bioenergy for sustainable development and the challenges faced. The results of the research are finally discussed, and in the conclusion, reference is made to the positive and negative sustainable development impacts of bioenergy today and in the foreseen development, and the implications of current practices and trends of different stakeholders and existing policies, programs, and projects in this field. This is finally concluded with messages for policy makers.

In order to meet the objectives of the research, the following steps were followed:

1. An overview of the development of the concept of Sustainable Development Impact Assessment and related application in Egypt for Renewable Energy projects was presented.
2. An investigation of the application of Sustainable Development Assessment (SDA) in Egypt and the procedural process of CDM projects as a main driving force of RE was made.
3. A study was conducted to investigate the current status of the bioenergy industry in Egypt, including biomass resources, biomass management, technologies, and existing projects and the challenges faced.
4. An investigation of the trends of energy and renewable energy policies, programs, and projects in Egypt with focus on biomass was made.
5. An overview of the air pollution problem in Egypt and its relation to biomass was made.
6. An overview of related legal framework, regulations, and other efforts to address this problem was made.
7. A newly introduced biomass technology was chosen as a representative example of efforts to promote bioenergy systems in Egypt, and used as a case study.
8. The theoretical background for the chosen case study was presented, followed by a presentation of the case study with an attempt to assess its sustainable development.
impacts with reference to the information previously gathered in the course of the research and the results of the field visit and interviews with stakeholders.

9. The findings of the research were then used to discuss the local strategic benefits and drawbacks of bioenergy technology in Egypt and to expand the discussion to include prospects for other bioenergy options, and make recommendations to promote improved planning for bioenergy systems and CDM projects in Egypt.

These steps will be carried out through literature surveys, interviews with stakeholders, and field visits. Calculations will be made using simple formulae for approximate estimations mainly using the IPCC (1996) guidelines for standard methodologies and procedures.

3. Sustainable Development Impact

Sustainable development has most commonly been defined as suggested in the 1987 Brundtland Commission report as

"… development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

-UN 1987

The field of sustainable development can be conceptually broken into its three interdependent pillars: environmental sustainability, economic sustainability, social sustainability.

However, although the Brundtland definition of SD gained widespread acceptance and its ambiguity proved useful in building broad coalitions of stakeholders, it provided little detail on what to sustain, to what extent and on what time scale (Bartelmus 2003, p. 61; Parris and Kates 2005). Therefore, the context of this term is essential for its interpretation.

In this research study, the context is renewable energy projects for sustainable development, and their positive and negative impacts. The focus is specifically on bioenergy systems.

An adequate and universally accepted methodology to assess and evaluate the impact of a bioenergy project on sustainable development would be to follow the guidance of the UNEP Riso Center as provided in their Clean Development Mechanism (CDM) guidebooks (Olhoff, A. et al, 2006; Dutscke, M. et al, 2006; Olsen, K.H. et al, 2006). These documents provide recommendations for CDM project developers and stakeholders to define, assess, and evaluate sustainable development impacts of CDM projects such as bioenergy projects. This section refers to SDA in the context of the CDM projects since all foreseen renewable energy projects in developing countries are increasingly being implemented in the framework of the CDM to benefit from the incentives for CO₂ reduction.

In 2004/2005, the total GHG emissions in Egypt were estimated at 137 Million ton of CO₂ equivalent, out of which more than 70% was emitted by the energy sector, including 35% attributed to the electricity sector (Georgy, R.Y., 2007). The concerned department in EEAA, the Egyptian Designated National Authority (DNA), has announced in January 2007 that CDM projects portfolio included more than 40 projects for CO₂ reduction of
which 29 have been accepted and/or approved by the DNA. However, little is mentioned about the local environmental and development impacts of such projects. The following sections attempt to present relevant methods to assess such impacts.

Furthermore, although the DNA is the authority responsible to evaluate and ensure the sustainability and prioritization of projects, this process is not carried out for every individual project in practice. In an interview with the head of the Climate Change Unit in EEAA, the DNA (2007), he explained that the projects are considered accepted based on the approved EIA provided as a prerequisite, and that is sufficient evidence for the sustainability of the project.

3.1. SDA of CDM Projects

CDM is a market-oriented mechanism to promote the Kyoto Protocol efforts for global greenhouse gas (GHG) reduction. The CDM is designed with the dual aim of assisting developing countries in achieving sustainable development (SD) and of assisting industrialized countries in achieving compliance with their GHG emissions reduction commitments. The SD dimension is a requirement of the CDM as provided in Article 12 of the Kyoto Protocol, which requires projects to be designed in a way that assists SD in the host country. Kyoto Protocol Article 12.2 mentions the purpose of achieving SD before mentioning emission reduction, explained as follows:

“*The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I (countries) in achieving compliance with their quantified emission limitation and reduction commitments under Article 3.*”

(Kyoto Protocol Article 12.2)

Annex I countries are developed countries and countries undergoing the process of transition to market economy. All Annex I countries have specific limitation targets for greenhouse gas emissions.

The SD consideration requirements clearly acknowledge the fact that CDM projects will have a number of impacts in the host countries, including impacts on economic and social development and on the local environment. National authorities are therefore encouraged to use the SD dimension to assess and identify synergies and compliance with national and local development goals in addition to internationally coordinated activities related to the development of Poverty Reduction Strategy Plans (PRSP) and to the Millennium Development Goals (MDG) implementation strategies.

The CDM may contribute to several SD objectives of developing countries, including:

- Poverty alleviation and employment generation.
- Local environmental benefits, such as cleaner air and water, and afforestation.
- Local environmental side benefits, such as health benefits from reduced local air pollution.
- Transfer of technology and know-how.
• Increased energy efficiency and conservation.
• Private and public sector capacity development.
• Sustainable energy production and diversification of resources.

Yet given the ambiguousness of the concept of SD and the subjectivity involved in assessing its impacts and the lack of consensus on its operational definition, the choice of SD criteria and procedures for assessing these criteria is a controversial and cumbersome issue. Multiple guidelines have been published to promote common understanding and recommend best practices to facilitate integrating the SD dimension into project plans (EcoSecurities 2002; Figueres 2002; Pembina 2003; Rosales, J. et al 2002, and 2003; Spalding-Fecher, 2002; Olhoff et al., 2006). In the available guidelines, SD is seen as an integrated part of the legal framework of the CDM and it aims to address the SD dimension on equal terms with GHG emission reduction.

However, despite the many guidelines, selecting of the SD criteria and the assessment of the SD impacts are sovereign matters of the host countries in the current operationalization of the Kyoto Protocol. Generally, in practice, little attention is paid to the assessment of SD impacts of CDM projects and there yet few suggestions on specific assessment methods (Olhoff et al., 2006). This might be due to the struggle of development countries to address immediate economic development concerns. Therefore, methods being developed for SD assessments must take into consideration the convenience and applicability to different host countries, which have different conditions, such as in development priorities or even in capabilities and capacity to conduct SD assessments. It is sometimes even argued that the SD impact assessment of project might only be adding to transaction costs and is a complication.

3.2. SDA In Egypt

Each country determines its strategy and priorities to optimize sustainable development synergies achievable in its CDM projects, or any development project. In Egypt, there has been a National Strategy Study (NSS) on the CDM, conducted in 2002, where all the sectors of the economy for suitable CDM project candidates have been screened based on the national priorities, of which (Egypt NSS 2002).

3.2.1. Multicriteria Analysis

Under the NSS, SD impacts of potential CDM project in Egypt were assessed using Multicriteria Analysis (MCA) (Olhoff, 2006). MCA is a useful tool where there is a decision to be made based on different types of information, all of which is relevant to a decision of the project, but which cannot all be incorporated into a single indicator such as Net Present Value or an Internal Rate of Return (IRR). MCA therefore has the advantage of allowing comparison of qualitative and quantitative data within a single framework. All relevant criteria of a decision option are listed and given scores and weights according to significance, thereby obtaining a total score for the option to compare with alternatives.

Using MCA, the NSS screened all sectors of the economy for suitable projects, focusing on those with the highest GHG emission reduction potential. These projects were for energy generation, renewable energy applications, transportation, energy efficiency in
industry, and Land Use, Land Use Change and Forestry (LULUCF). Based on this screening, an initial portfolio of 22 projects was selected.

A cost calculation was carried out for all the selected projects, providing information on marginal abatement cost (MAC), the cost of saved carbon, GHG reduction potential, and the expected payback period. After the cost calculation, the each projects was assessed on a proposed set of national SD criteria covering economic, environmental, and social dimensions, in addition to criteria important to international investors. Finally, 6 CDM projects were proposed for Egypt (Egypt NSS 2002).

The respective weights assigned to each criterion reflect the national priorities. The case in Egypt is that a maximum an allocated weight of 70 was given to the criteria of the international investors’ point of view from a total of 180. An overview of Egypt’s NSS SD criteria, indicators and weights is provided in the following section. It clearly emphasizes criteria that appeal to international investors in addition to the criteria of the three pillars of SD; Economic, Environmental, and Social Sustainability as shown in Table 1.
Table 1: Overview of Egypt’s NSS SD criteria, indicators and weights (Olhoff, 2006).

<table>
<thead>
<tr>
<th>Criteria Indicators</th>
<th>Allocated Weight</th>
<th>L</th>
<th>M</th>
<th>H</th>
<th>Score</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Economic</td>
<td>(80)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.01 Infrastructure</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>L=replacing; M=expanding</td>
<td>H=creating</td>
</tr>
<tr>
<td>1.02 Export Potential/Import substitution</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>L=&lt;15%; 15%&lt;M=&lt;35%; H&gt;35% of annual production</td>
<td></td>
</tr>
<tr>
<td>1.03 Payback period</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td>L&gt;8 or no payback; 5&lt;M=&lt;8; 2&lt;H=&lt;5 years</td>
<td></td>
</tr>
<tr>
<td>1.04 Energy Savings</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td>L=&lt;10%; 10%&lt;M=&lt;15%; H&gt;15% TOE/Year of BAU</td>
<td></td>
</tr>
<tr>
<td>1.05 State of technology</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>L=Commercially Available; M=Modern Technology; H=Advanced Technology</td>
<td></td>
</tr>
<tr>
<td>2 Environmental</td>
<td>(20)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.01 Improvement in environmental performance</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td>L= Comply with Egyptian Legislation; M=Comply with Annex I countries legislation, H=Significantly better than annex I countries legislation.</td>
<td></td>
</tr>
<tr>
<td>3 Social</td>
<td>(10)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.01 Employment</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>L=Job Reduction by Project; M=No Significant Change in number of jobs, H=Significant creation of jobs.</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>110</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Criteria from International Investors’ View</td>
<td>(70)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.01 Profitability</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td>L=No return or loss on investment; M=Return on investment =&lt;6%; H=ROI&gt;=6%</td>
<td></td>
</tr>
<tr>
<td>4.02 Investor Image</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td>L=Project might contribute to a negative image of the investor or has no impact on image at all; M=Impact of project on investors image is slightly positive; H=Very positive</td>
<td></td>
</tr>
<tr>
<td>4.03 Project risk</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td>L=&lt;50%; 50%&lt;M=&lt;90%; H&gt;90% of the probability of the generation of the expected CERs.</td>
<td></td>
</tr>
<tr>
<td>Subtotal</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>180</td>
<td></td>
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</tbody>
</table>
Compared to other SDA methods and indicators used in different countries and organizations, the Egyptian NSS. The Environmental impact in the NSS is assessed using only one indicator showing the compliance with national and international environmental legislation. The social aspect is also assessed using one indicator showing impact on job creation, and it is given half the weight given to the environmental impact, 10 out of a total of 180.

### 3.2.2. Allocation of Weights

It is clear that, between the three pillars of sustainability, the most weight by far was allocated to Economic criteria indicators, totaling 80 out of 180. Only a weight of 10 was given to social sustainability, and it was indicated by employment generation (or reduction) of the project, and a weight of 20 was given to environmental sustainability, indicated with reference to compliance to local and international environmental legislation.

In a study made on five of the projects that were highly ranked, it was concluded the ranking seems to be very sensitive to the value of the pay back indicator under the economic criteria (Olhoff, 2006). As a result of such a high weight allocated to the economic indicators, the project that scores a maximum on the social and environmental criteria, a LULUCF project, only ranked fourth out of the five studied. Notably, these economic indicators do not consider the global environmental impact as no account is taken of the carbon benefits of the project in calculating the NPV. Therefore, carbon valuation is the next part of the valuation of the NPV to test the profitability of the CDM project and the minimum value per ton of Carbon needed.

Among the project categories proposed in the NSS, were organic waste management and municipal solid waste methane utilization, which regards biomass utilization as a promising development project in Egypt. However, most focus was specifically on landfill gas recovery, whereas many other biomass technologies may be feasible.

### 3.2.3. The SSN Matrix Tool

The international NGO South South North (SSN) has developed a commonly used checklist tool for appraising the suitability of proposed CDM projects (Olhoff, 2006). This tool has not been used in Egypt, but applied in projects in Bangladesh, Indonesia, South Africa, and Brazil. It has been provided in the research on CDM SDA of Olhoff (2006) as a popular alternative tool among others. It is explained here to demonstrate the contrast in comprehensiveness of other used SDA tools compared to the MCA methodology used in Egypt.

The tool is called the SSN Matrix Tool and it consists of eligibility criteria, additionality filters, sustainable development indicators, and feasibility indicators (SSN 2003). The SD indicators of this checklist demonstrate how the environmental and social aspect of the SDA can be expanded to include essential indicators that are given less priority in SDA procedures elsewhere such as in the case of the NSS of Egypt.

In the SSN matrix tool, the SD indicators for social and environmental sustainability are as follows, listed with the corresponding means of measurement:
Local/regional/global environment
- GHG emissions: Tons of CO2 equivalent.
- Water quantity and quality
  - Water quantity: number of people with access to water supply
  - Water quality: concentration of main pollutants (including BOD and others)
- Local air quality: Tons of SOx, NOx, particulate matters etc.
- Other pollutants: Pollutants not already considered to the environment, including solid, liquid and gaseous wastes.
- Soil condition (quality and quantity): Concentration of most relevant soil pollutants, erosion and the extent of land use changes.
- Biodiversity: Destruction or alteration of natural habitat and species

Social sustainability and development
- Employment (qualitative): Highly or poorly qualified, temporary or permanent.
- Livelihoods of the poor:
  - Poverty alleviation: Change in number of people living above income poverty line.
  - Distributional equity: Changes in income and improved opportunities
  - Access to services: water, health, education, access to facilities, etc.
  - Access to energy services: Coverage of reliable and affordable clean energy services, security of energy supply
- Human and institutional capacity:
- Empowerment: access of local people to and their participation in community institutions and decision-making processes.
- Effects on education and skills.
- Gender equality: empowerment, education/skills and livelihoods of women

Economic and technological development
- Employment: Net employment generation
- Balance of payments: Net foreign currency requirements
- Technological self reliance: Replicability, hard currency liability, skills development, technology transfer

The performance of a project is assessed using the listed SD indicators each assigned a score on a scale from -2 to +2 as compared to the BAU scenario (i.e. in the absence of the projects).

Despite the comprehensiveness and completeness of the indicators, some disadvantages arise due to the difficulty to provide information on all relevant indicators for all projects (Olhoff, 2006). Furthermore, the extensive use of qualitative indicators results in high subjectivity and possible bias in the application of scores.

3.2.4. Designated National Authority (DNA)
Egypt signed and ratified the Kyoto Protocol before entry into force on February 16, 2005, therefore qualifying as a host country for CDM projects since it is classified as a non-Annex-1 country. The host country should be responsible to ensure that projects are consistent with its development goals.
The SDA approach as explained so far was in regards to screening of different sectors in Egypt in the initial stages of building the capacity of the Egyptian DNA. Presently, for each individual CDM project to be implemented, an approval of the Designated National Authority is required. The Designated National Authority is the component responsible for all related CDM activities in Egypt and is affiliated to EEAA.

The required steps to qualify a project within CDM are:

1. Preparing Project Idea Note (PIN).
3. Letter of No Objection on the project from the Designated National Authority (DNA).
4. Submitting the Project Design Document (PDD) to the Designated Operational Entity (DOE) affiliated to the Executive Board (EB) for ratification before the final approval of the EB.
5. Accepted project will be registered in EB as a CDM one within 8 weeks, against paying fees for registration, follow up, monitoring and verification (NREA Annual Report 2006)

At the third step as listed above, the DNA is expected to confirm the eligibility of the project ensuring that it is voluntary, satisfies additionality criteria, satisfies national criteria, and contributes to national sustainable development.

However, as mentioned earlier, any project is required to have an approved EIA, which is found sufficient by the DNA to approve the project. With that approach, no more is done by the DNA than what is legally binding according to the environmental law. The related provisions of environmental law in Egypt are further explained in section 5.3.

4. Bioenergy in Egypt

Bioenergy, although the oldest renewable energy technology in Egypt, has received little attention as a promising technology for development, and most efforts of the Egyptian government in the recent years to promote renewable energy have been directed towards wind energy and to some extent solar energy. However, many researchers referred to the vast potential of unused biomass resources in Egypt and the potential for promoting local development and environmental sustainability through growing this industry.

4.1. Background

The energy sector in Egypt is managed through two different ministries, the Ministry of Electricity and Energy (MOEE) and the Ministry of Petroleum (MOP). However, energy activities have been increasingly recognized as one of the major sources of pollution threatening the land, water, and air quality, and therefore the Egyptian Environmental Affairs Agency (EEAA) has come to play a major role in the sustainability of the energy sector today.

The Egyptian Government is currently facing a challenge in its energy strategy, trying to balance between satisfying the increasing demand on national primary energy (over 94% met by subsidized fossil fuels; oil and natural gas) on one hand, and maintaining revenues from oil and gas exports on the other hand. In the meantime, the risk of accelerated
depletion rates of proven reserves is growing, which implies that Egypt is increasingly becoming a net importer of oil.

Since 1970s, Ministry of Electricity & Energy (MOEE) has acknowledged the need to tap into Renewable Energy (RE) resources for sustainable development. In the early 1980s, a renewable energy strategy was formulated as an integral part of the national energy plan of Egypt (NREA 2007). The strategy has been revised in view of the projections for possible RE technologies and application options, available financing sources, and investment opportunities in this field. This has resulted in the establishment New and Renewable Energy Authority (NREA) established in 1986 under the MOEE.

NREA was established to act as the national focal point for the introduction and development of renewable energy technologies in Egypt and for the implementation of related energy conservation programs. It is entrusted to plan and implement renewable energy programs in coordination with other concerned national and international institutions. Currently, the national strategy targets to satisfy 3% of the electric energy demand from renewable energy resources by the year 2010 (NREA 2007).

However, most of the focus of NREA has so far been on Wind Energy and Solar Energy, which have proven more attractive to international investors as reflected in the current projects activities in this field today. This is notably influenced by the CDM incentives and obligations under the Kyoto protocol for CO2 reduction in Annex 1 countries. The promotion of CDM generally favour larger projects, and projects that can fit into the centralized energy system that Egypt maintains, i.e. not projects of decentralized energy generation.

The authority responsible for all related CDM activities Egypt is the Designated National Authority (DNA) for CDM established in 2005 as part of the EEAA. The EEAA is the executive arm of the Ministry of State for Environmental Affairs acting as the coordinating body for environmental activities in Egypt. Among the activities of EEAA that relate to the energy sector are inspection of industrial facilities, reviewing and approving EIAs, drafting environmental action plans, and promoting environmental projects such as GHG reduction projects under the CDM. EEAA was established in accordance to Law 4/1994 for the protection of the environment.

Emerging renewable energy resources in Egypt are three: Wind Energy, Solar Energy (thermal and photovoltaic), and Biomass Energy (Bioenergy). Hydropower, although abundant, is not an emerging technology, and therefore not included in the RE targets set by the government as it is considered a default resource. Furthermore, uses of other renewable energies such as geothermal energy or wave energy and others have not proven feasible in Egypt, or have not received attention. The three RE resources, Wind, Solar, and Biomass, are today receiving notable support from the government driven by international incentives for RE promotion and for net CO2 reduction as it reduces dependence on fossil fuels. Today, wind power plants installed capacity in Egypt have reached 230 MW, and other achievements include 30 MW solar thermal power in a 150 MW Combined Cycle System Power Plant, among other small-scale solar energy projects. On the other hand, development in the field of bioenergy systems has been relatively slower (NREA, 2006).

In late 2006, the Supreme Council of Energy was established, and the Government of Egypt is currently undergoing the formulation of its own National Sustainable
Development Study, coordinated through the Ministry of State for Environmental Affairs. Energy is a key component of this strategy that aims to ensure sustainable energy production and utilization in all aspects. The energy sector is therefore currently undergoing many changes for improvement, and a new electricity act for RE is due to be issued by the end of the present year, 2007 (Enviro 2007). This act will aim to facilitate the advent and market penetration of RE technologies in Egypt.

In light of all the recent developments to promote renewable energy for CO2 reduction to increase production, to diversify fuel supply, to better utilize existing energy resources, and to encourage projects generating job opportunities and attracting investments, bioenergy systems are likely to have fertile land for growth in the coming years. This growth has already started, exemplified in many bioenergy projects such as for biogas production, biogasification, and charcoal production.

### 4.2. Energy and Environment in Egypt

Egypt is a net exporter of energy, with major recent discoveries of natural gas now assuming increasing importance compared to oil production, which has now stabilized (World Bank 2003). Both oil products and natural gas meet 46% of the primary energy requirement, with 7.5% met by hydroelectricity. As for electricity, natural gas is responsible for over 90% of thermal electricity generation. The majority of the power plants have been converted from burning fuel oil (mazout) to the less polluting natural gas (SOE 2005). New Combined Cycle Gas Turbines (CCGT) plants being constructed to meet new demand.

Oil has been produced and refined in Egypt for a long period of time in aging refineries, which means that the refinery sector produces a surplus of low value products, such as fuel oil, and has a deficit of high value products such as gas oil and LPG. The balance of payments in the oil sector is now negative (World Bank 2003).

In the study of damage costs of the energy sector by the World Bank (2003), the impact of different pollutants where analysed over a period of 10 years projected to 2012. The pollutants specifically five local pollutants, sulfur dioxide (SO2), nitrogen oxides (NOx), carbon monoxide (CO), particulates (PM10) and non-methane volatile organic compounds (NMVOCs), and two global pollutants, carbon dioxide and methane (CO2 and CH4). Results showed that if no mitigation actions are taken, increased consumption is projected to increase local damage costs from the energy and agricultural residues by 25% to LE 8 billion/year (USD 1.7 billion) in 2010/2011. The major contributions to damage costs in the future are expected to be largely from those sectors.

One of the proposed measures to address the scarcity of energy resources and the damage costs ensued is to promote clean RE technologies such as bioenergy, and to manage collection of agricultural residues. These are some of the many commitments included in the National Environmental Action Plan of Egypt (NEAP 2002).

### 4.3. Biomass Resources

Emergence of bioenergy systems in any country is determined by the type and quantities of resources available, among other factors. Biomass can generally be divided into four
categories according to its origin: Energy crops solely dedicated to bioenergy systems, post-harvest residues, organic by-products, and organic waste (DGS, 2005).

In Egypt, the total amount of biomass is of the order of 60 million ton/y, equivalent to about 20 million toe/y (Hinnawy, 2006). They are mainly of the following types, listed with examples found in Egypt:

1. Agricultural residues (e.g. crop residues)
2. Animal by-products (e.g. dung)
3. Agro-industrial by-products (e.g. rice husk, bagasse)
4. Exotic plants (e.g. water hyacinth, reeds, etc)
   - Oil crops (e.g. rape seed, Jatropha, etc.)
   - Other crops (e.g. elephant grass, etc.)
5. Municipal waste, which includes:
   - Municipal solid wastes (mixed with non-organic wastes).
   - Sewage sludge.

Furthermore, energy crops, specifically Jatropha, are currently emerging as a new promising renewable energy source for producing biodiesel (SOE 2005).

As for municipal solid waste in urban areas, the following table shows how organic material is typically the main constituent at up to 60% of solid waste in Egypt:

### Table 2: Typical Municipal Solid Waste Composition in Egypt according to 2005 estimates (EEAA 2005)

<table>
<thead>
<tr>
<th>TYPE OF WASTE</th>
<th>PERCENTAGE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORGANIC</td>
<td>50-60</td>
</tr>
<tr>
<td>PAPER AND CARTON</td>
<td>10-25</td>
</tr>
<tr>
<td>PLASTIC</td>
<td>3-12</td>
</tr>
<tr>
<td>GLASS</td>
<td>1-5</td>
</tr>
<tr>
<td>MINERALS</td>
<td>1.5-7</td>
</tr>
<tr>
<td>RAGS</td>
<td>1.2-7</td>
</tr>
<tr>
<td>OTHER MATERIALS</td>
<td>11-30</td>
</tr>
</tbody>
</table>

(Relative density: 0.3 ton/m³, and humidity: 30-40%)

#### 4.4. Agricultural Wastes

The estimated amount of agricultural waste in Egypt ranges from 30 to 35 million tons (AWRU 2005). Some of the agricultural waste is used as animal fodder, and other waste is used as fuel in indoor primitive ovens that causes health problems and damage to the environment. The rest is burned in the field such as rice straw, causing local and regional air pollution problems.

The three crops with the generating the most amount of waste are rice, wheat, and sugar cane. The type and quantity of agricultural waste in Egypt varies in location and in time (harvest season) as farmers cultivate the most profitable crops given the local conditions and season. This is a significant issue when studying the nature of the agricultural residue supply quantity varying in time and location. Table 3 shows the amounts of the different types of agricultural wastes in Egypt and the corresponding time of harvest.
Table 3: Amounts of agricultural wastes in Egypt (Source: AWRU 2005)

<table>
<thead>
<tr>
<th>Waste source</th>
<th>Amount (million ton)</th>
<th>Time of harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice straw</td>
<td>3.5</td>
<td>September/October</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>7.3</td>
<td>May / June</td>
</tr>
<tr>
<td>Corn</td>
<td>3.2</td>
<td>September/October</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>8.7</td>
<td>September/October</td>
</tr>
<tr>
<td>Cotton stalks</td>
<td>1.8</td>
<td>December /April</td>
</tr>
<tr>
<td>Barely</td>
<td>0.6</td>
<td>March /April</td>
</tr>
<tr>
<td>Vegetable residues</td>
<td>3.2</td>
<td>All the year</td>
</tr>
<tr>
<td>Fruit residues</td>
<td>1.5</td>
<td>All the year</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>1.2</td>
<td>June /July</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

The time of harvest is mostly important in the case of rice straw, since it is burnt in the open field during a period of unfavorable atmospheric conditions as explained in coming sections. The recent studies show that the burning rice straw increases black smoke over Cairo about 42% but in the rest of year the responsibility of burning agriculture wastes does not exceed 6% (AWRU 2005). The geographical distribution of rice cultivation is indicated in Table 4.

Table 4: Rice cultivation area and rice straw production [Source: AWRU 2005]

<table>
<thead>
<tr>
<th>Governorates</th>
<th>Area (000 acres)</th>
<th>Amount of rice straw (000 ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qaliubia</td>
<td>17.6</td>
<td>35.2</td>
</tr>
<tr>
<td>Kafr El Sheikh</td>
<td>255</td>
<td>510</td>
</tr>
<tr>
<td>Daqahlia</td>
<td>437.6</td>
<td>875.2</td>
</tr>
<tr>
<td>Beheira</td>
<td>195.8</td>
<td>391.6</td>
</tr>
<tr>
<td>Sharqia</td>
<td>271</td>
<td>542</td>
</tr>
<tr>
<td>Gharbiyah</td>
<td>161.7</td>
<td>323.4</td>
</tr>
<tr>
<td>Dumiat</td>
<td>65.8</td>
<td>131.6</td>
</tr>
<tr>
<td>Fayoum</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>1,424.5</td>
<td>2,849.00</td>
</tr>
</tbody>
</table>

Table 4 shows that most rice straw generation is in Daqahlia, Kafr El-Sheikh, and Sharqia governorates. The table also demonstrate how widely distributed the rice straw generation is, which is a challenge for feasible waste collection management. Furthermore, the
geographical location relative to wind direction and urban agglomerates is a critical issue as explained in the coming sections.

4.5. Management of Agriculture Waste

The role of the Egyptian Environmental Affairs Agency (EEAA) to deal with agricultural waste in Egypt is centered in the Agricultural Waste Recycling Unit (AWRU) of EEAA, which is closely cooperating with the Ministry of Agriculture and Land Reclamation (MALR). Other concerned organizational units in EEAA are the Air Quality Department due to their concern over seasonal open burning of agricultural wastes, and the Department of Solid Wastes, although to a lesser extent since their major concern is hazardous wastes and municipal solid waste.

The role of AWRU over the recent years to address the rice straw open burning problem has been as follows (AWRU 2005):

- Mobilize tractors and compactors: Numerous compactors have been mobilized in order to facilitate handling and transport of rice straw through the autumn harvest season.
- Coordinate with Ministry of state for Military Production to promote manufacturing of new tractors and compactors. 300 compactors and 100 tractors have been provided in 2005 (AWRU 2005).
- Promote factories producing compost such as:
  - Two factories established in Sharkia governorate to produce compost. They consume 300,000 tons of rice straw annually to produce 80,000 tons of compost yearly.
  - One factory established in Dakahlia governorate to produce compost. It consumes 150,000 tons of rice straw annually to produce 40,000 tons of compost.
- Promote alternative Gasification units: Two biogasification units have been established in the governorates of Sharkia and Dakahlia to produce producer gas. They have the capacity to consume 30,000 tons of rice straw annually.
- Provide training programs on agricultural waste recycling, such as:
  - Training small farmers and NGOs cooperative with extension department in Ministry of Agriculture in 15 governorates to manage agricultural waste by composting and Implementing on-site compost demonstration projects.
  - Training small farmers and NGOs in cooperation with the extensions of the Ministry of Agriculture in 15 governorates for sound management of agricultural waste by chemical conversion to animal fodder.
- Promote alternative methods for beneficial uses of rice straw such as vegetable production cultivated on compacted rice straw beds such as straw berry, pepper, tomato, mushrooms, and cucumber in the open fields or under green houses.
All activities are conducted in coordination with the Ministry of Agriculture and Land Reclamation (MALR). The MALR has a sector administrating subdivisions (agriculture extensions) of MALR in the governorates of Egypt.

At the village level, the cooperative unit of the village includes one or more technical advisor who can have contact with farmers, and should be capable of managing all aspects concerning regulations set for the farmers.

### 4.6. Bioenergy Systems

With the abundance of the biomass resources, and the increasing awareness about their value, Bioenergy Systems are slowly developing in Egypt to benefit from opportunities for sustainable energy production.

Bioenergy systems convert the solar energy stored in biomass into heat, mechanical energy, and electricity. The conversion processes can be classified into five categories: direct combustion systems, co-firing systems, thermo-chemical processes, biochemical processes, and physico-chemical conversion (Hinnawi 2006).

The existing bioenergy systems in Egypt today are:

**Biomass Combustion:** The oldest bioenergy technology in Egypt, mainly in rural areas using agricultural residues and dung cakes in brick stoves. Although kerosene and LPG cylinders (butagas) replaced most of the traditional biomass. However, biomass is still used in about 17% of rural households and remote areas (Hinnawi 2006). On a larger scale direct biomass combustion technology is used in combined heat and power (CHP) production at sugar mills. The eight mills in Egypt add up to about 135MW of total installed cogeneration capacity. Prospects to export to the grid however are limited due to the low rates of electricity export tariffs.

**Biomass Briquetting:** Pilot experiments on briquetting some agricultural residues have been carried out by NREA and by some NGOs and in cooperation with the Academy of Scientific Research & Technology (NREA 2006). Industrial scale units (SMEs) have still not been produced.

**Carbonization:** Charcoal production is an old small-scale industry in Egypt. It is normally carried out by the informal sector in elementary kilns, using old fruit trees, tree branches, wood from old boxes, etc. Charcoal kilns are one of the major sources of air pollution in the Greater Cairo region and other governorates. NREA is aiming to upgrade this technology in cooperation with US-Egypt Joint Science & Technology Board affiliated to Academy of Scientific Research & Technology (NREA 2006). The main concept of the kiln under development is extracting the evolved gases and vapor during carbonization, separating and treating the liquid tars as liquid by product. The combustible gases could be used directly as the source of energy for carbonization. The system productivity is around 0.5 - 1 ton/day of charcoal. This development is especially needed due to the high environmental impact caused by the inefficient kilns currently in operation.

**Biogasification:** Two Chinese gasification plants have been installed by the Egyptian Environmental Affairs Agency (EEAA) in rural areas in Sharkia and Dakahlia governorates.
to produce biogas from rice straw. The two plants are now under operation since 2003, producing about 250m3/day of producer gas providing for over 100 families, which is still below 40% of their capacities. They are considered demonstrational projects, and they have not yet been replicated due to several barriers that will be further discussed in this research.

**Anaerobic Fermentation:** Research and development in this field is conducted in the Agricultural Research Centre, and at the National Research Centre, and by NGOs. Demonstration units (household biogas plants Indian and Chinese types) have been constructed in Egypt, mostly financed by GEF Small Grants Program and other donor assistance. Most household plants are of the Indian type with a floating gas storage drum, and the remaining are of the Chinese fixed dome type. A DANIDA evaluation of biogas plants carried out in 2000 indicated that of 850 household plants constructed, about 50% of the plants were not operating because of a series of problems; poor construction and quality of equipment, inadequate maintenance, improper feeding of the digester, and lack of follow-up services (DANIDA 2000). One large-scale biogas system has been constructed at Gabal Asfar sewage treatment plant near Cairo (Hinnawi, 2006). It is a 22000 cubic meter digester constructed to produce 18 MW of power to provide the treatment plant with part of its electricity needs.

**Biodiesel Production:** A Biodiesel plant has been founded as a joint Egyptian-Austrian venture (Sokhna Biodiesel Co.) along the Gulf of Suez to produce biodiesel from oil extracted from Jatropha plantations established near Luxor (Hinnawi 2006). It is planned to produce about 90,000t of biodiesel for export.

### 4.7. Barriers

Despite the abundance of biomass resources in Egypt, the actual practical and economical potential is dependent on many factors, which must be considered before projecting a realistic vision for bioenergy in Egypt. One of the main challenges is that energy is heavily subsidized (Eberhard A. et al) in Egypt, and so prices do not reflect the cost of supply, making it more difficult for bioenergy to compete in the energy market. However, energy prices are presently being rationalized. This policy aims to improve the sector performance and to attract private investors to invest in Build-Own-Operate-Transfer (BOOT) projects.

However, since the provision of lifeline-subsidized rates of electricity to select disadvantaged groups is essential for equity considerations, cross-subsidization is inevitable. The government of Egypt has recently approved a number of measures to address the tariff issue. These include the approval of 5% annual energy tariff (Eberhard A. et al) adjustments up to 2009/2010. The Egyptian Electricity Holding Company (EEHC) currently use lifeline tariffs for small domestic consumers, and low tariffs for small agricultural consumers, involving cross-subsidization to benefit the weaker sections of the society.

In a project by the Energy Research Center (ERC, 2006) of Cairo University for the Industrial Modernization Center (IMC), an extensive study of the bioenergy industry was conducted and it identified the main barriers summarized as follows:

**Economic and financial barriers:** A supportive financial environment is needed to bear the high initial costs of bioenergy systems. Furthermore, financial institutions perceive
them as high-risk. Existing capital markets must support development of small and medium
decentralized projects. Therefore, financial institutions/agencies must prove efficient in
handling such small capital requirements.

**Awareness and information barriers:** Lack of reliable information on biomass resources,
such as a resources database, especially at the local level, discourages investors.
Furthermore, dissemination of public information about bioenergy technology and wider
public participation in its development are essential for social acceptability.

**Technical barriers:** There is a lack of local expertise, manufacturers, and agents, and lack
of maintenance and standardization of equipment, and lack of adequate demonstration
projects, which implies high-risks for investors. This also applies to the relatively mature
bioenergy technologies such as gasification and anaerobic fermentation. Notably, there are
no manufacturing companies dedicated to bioenergy systems existing in Egypt.

**Market barriers:** Existing policies and plans are in favor of large conventional energy
technologies, and RE is mainly considered for grid-connected power generation.
Furthermore, pricing policies do not take into account the high environmental costs of
conventional energy sources as compared to renewable energy. Another challenge is the
absence of a level playing field, since subsidization of fuels (LPG, kerosene and diesel) and
electricity creates unfair competition with bioenergy sources.

**Institutional and policy barriers:** Development of bioenergy requires decentralized
approaches; there is currently a lack of national-level coordination and lack of an effective
institution to promote bioenergy technologies and to collect and analyze data on energy
supply and demand in each locality. The few NGOs involved in bioenergy activities are
mainly driven by the availability of funding from donors for small demonstration projects,
rather than influenced by a long-term national strategy (El-Haggar 2007).

The study recommended several policy measures to overcome these barriers. The proposed
measures are to consider promoting the following:

- Investment incentives such as investment subsidies, or tax incentives,
- Production incentives (per unit of energy generated),
- Power Purchasing agreements under which utilities buy power from renewable
  energy suppliers,
- Renewable Energy set-asides, where a percentage of total electricity generation
  capacity should come from renewable sources.
- Public Private Partnerships for the development and demonstration of bioenergy
  systems, where involvement of the public sector often instills confidence of the
  private investor.
- Research, development and demonstration in general, aiming to improve self-
  reliance and local manufacturing and services and to stimulate public interest.

In this research however, it is notable that compared to the other emerging RE technologies
in Egypt, namely Solar and Wind energy, bioenergy was found to be the only technology
that can have all of its components produced locally in Egypt (ERC 2006). This study
referred to biogas plants as compared to solar thermal, solar photovoltaic and wind energy.
Furthermore, in the latest study by UNEP (2007) on energy efficiency and renewable energy in Egypt, it was stressed that in the course of developing sustainable energy strategies in Egypt, all proposed policies are often drafted, revised, approved, and adopted by technocrats and professionals representing only the supply side of the energy chain (Georgy R.Y., 2007). The study explains that this scheme had functioned well for the conventional forms of energy (being commodities) like electricity, NG, and oil products. However the same scheme has failed to succeed in the case of RE utilization and Rational Use of Energy (RUE) as in most of the cases the end-user is not only a passive buyer of a commodity, but rather more active and involved in the production and/or utilization of energy. The social aspect is essential. The study concludes that, in order to be successful, RUE and RE strategies together with accompanying tools and measures have to be developed through deep negotiations and engagement of end-user associations.

5. **Biomass and air pollution**

Management of municipal solid waste is considered one of the most pressing environmental problems in Egypt in addition to agricultural wastes due to poor collection and disposal methods. Out of 60 million tons of waste generated annually, municipal solid waste accounts for 15 million tons. The remaining quantities include agricultural waste, construction and demolition wastes, industrial waste, wastewater sludge and waste from clearing of waterways (JICA 2007).

Abundance of wasted biomass such as agricultural or municipal waste may cause significant environmental damage to soil, water, and air quality, such as through mixing, leaching, and combusting, among many other mechanisms that allow biomass to affect the ecosystem. In Egypt, the most felt impact of misuse and mismanagement of biomass resources is the impact on air pollution partly resulting from uncontrolled open burning of agricultural wastes in the delta region, in addition to pollution from municipal solid wastes accumulating in urban areas.

The most problematic agricultural waste is rice straw due to the timing of its harvest and its location upwind urban areas. Therefore improved management of biomass resources, and above all, rice straw, could contribute significantly to the improvement of air quality in Greater Cairo, which is a dense urban agglomerate that hosts more than 20% of the entire nation’s population.

5.1. **Seasonal black cloud in Cairo**

First widely exposed in the media in 1999, the yearly phenomena of the dark haze covering the skies of Cairo city and its suffocating characteristics became a widespread public concern and has ever since been closely followed up by the media, describing it as a "black cloud" (El-Haggar 2003). The black cloud to the observer is a brown haze with an unpleasant odor in a stable climatic condition of little or no wind. The direct impacts are eye irritation, difficulty to breathe, and impeding vision. It is observed in Cairo city every autumn in the months of October and November.
5.1.1. Pollutants

The main pollutants in the air of Cairo are Lead, Sulfur dioxide, Nitrogen dioxide, Carbon monoxide, suspended particulate matter (SPM), and Ozone (EEAA Air qual, 2006a).

SPM is thought by researchers to be the main air pollution problem (EIMP 2001). It is a mixture of solid and liquid particles suspended in air classified as follows:

- PM$_{10}$ are coarse inhalable (thoracic) particulates, less than 10 micro-meters (µm) in diameter
- PM$_{2.5}$ are fine particulates, less than 2.5 micro-meters (µm) in diameter
- Organic and inorganic eg. dust, sand, metals, wood particles, smoke, soot, etc.

Although individual particles are invisible to the naked eye, they can accumulate and appear as visible clouds. This particle pollution, especially fine particles, contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems.

An assessment of health aspects of particulate matter (PM) was conducted by WHO concluding that the fine particles are strongly associated with mortality, hospitalization for cardio-pulmonary disease and other endpoints (WHO 2004). The WHO air quality guidelines state that the range of health effects is broad, but are predominantly to the respiratory and cardiovascular systems (WHO 2005).

Particle pollution may result from anthropogenic activities such fuel combustion in industries and natural phenomena, which in Egypt is mainly from wind blown dust from the arid areas of surrounding desert [EIMP 2001].

5.1.2. The Causes

After several years of research by the scientific society, there is consensus about the causes of the seasonal black cloud phenomena, but opinions widely vary regarding the relative significance of each pollutant, the contribution of each source and the extent to which this phenomenon is affected by natural factors. The findings of the Egyptian Environmental Affairs Agency (EEAA), the executive arm of the Ministry of Environment, are summarized as listed below, regarding the Natural and Anthropogenic causes of the black cloud formation [EEAA 2006a].

- Climatic conditions allow concentration of pollutants close to the ground in Cairo city due to:
  - Weak winds
  - Changes in temperature
  - Other factors causing stability or slow wind speed

- The topographic nature of Cairo city results in trapping air pollutants and limiting the transportation of suspended particulate matter (SPM) in air, characterized by:
  - The topography of the Nile valley between the high landscapes of Giza (the western hills) and Al-Muqattam (the eastern hills)
  - The urban edifices and the topography of the dense urbanity
The anthropogenic factors include the sources of pollutants from local sources in Cairo city and also from sources in neighboring governorates as prevailing winds carry over pollutants. The main sources are:
  - Vehicles fuelled on gasoline and diesel.
  - Industry (smelters, brick kilns, metal industries, cement industry, and sources of mazot combustion, etc)
  - Open burning of solid wastes
  - Open burning of agricultural wastes

However, in reviewing the literature, the respective contribution of each source has not yet been thoroughly proven and the dynamics of the phenomenon needs further studies. For example, in certain occasions in the year, the same conditions for the formation of a black cloud may coincide yet no black cloud is formed [Wahab 2006]. Despite the insufficient knowledge about the contribution of different sources and factors, the current Minister of State for Environmental Affairs (MSEA) has recently stated to the press that this issue was tackled in depth by different bodies, and the findings can so far be summarized as follows as stated to the press regarding the acute air pollution episode commonly known as the “black cloud” episode:

“Cars exhaust represents 25 % of the (black cloud) problem. Factories, major and small industries 25 %. Burning of industrial, agricultural, municipal wastes 30 %. This in addition to the geographic place of Cairo as well as its climatic conditions during October and November.”

-C.E.B.C 2005

For the annual air quality in Greater Cairo region, an extensive study on annual air pollution levels and contribution of different source categories was conducted in 2001 within the Cairo Air Improvement Project (CAIP) in EEAA. The study concluded the following percentages attributed to the respective source categories for the total annual load of pollution with suspended chest particles (PM10) in Greater Cairo air (MSEA 2006):
  - Solid municipal waste burning in the open air accounts for 36%
  - Exhaust gases accounts for 26%,
  - Industrial emissions for 32%,
  - Agriculture waste open burning for 6%.

Therefore, open burning of solid wastes and agriculture wastes largely contribute to air pollution in Greater Cairo and Egypt in general, whether during the air pollution episode or over the entire year. The contribution of open burning is also notably larger during the black cloud air pollution episode.

5.2. Impacts of Open Burning

In this section, the impacts of open burning will be explained on a global scale and on a local or regional scale, with a presentation of some of the impacts on the economy to show the magnitude of the externalities entailed.
5.2.1. Global Impact

Open burning of crop residues, like the burning of rice straw, is not thought to be a net source of carbon dioxide (CO₂) because the carbon released to the atmosphere during burning is reabsorbed during the next growing season. However, crop residue burning is a significant net source of CH₄, CO, NOₓ, and N₂O, which contribute to global warming where CO and O₃ are indirect GHGs (IPCC 2006). On the other hand, burning of agricultural crop residues as an energy source implies that burning would occur under controlled conditions and thus reducing emissions of GHGs as compared to open burning. The greenhouse gases contribution to global warming is indicated by its calculated Global Warming Potential (GWP), where a unit is equivalent to the global warming impact of 1 ton of CO₂ emissions as the reference. CH₄ and NOₓ have a GWP of 23 and 296 respectively over a period of 100 years (IPCC 2001).

The emission of chemically active gases, including carbon monoxide, nonmethane hydrocarbons, and nitric oxide, along with methane, also lead to the chemical production of tropospheric ozone, another greenhouse gas, as well as control the concentration of the hydroxyl radical, which regulates the lifetime of almost every atmospheric gas (Levine 1994). This is the reason they are classified as indirect GHGs.

5.2.2. Local Impact

The environmental impact of agricultural waste burning that is most felt by the public in Egypt, specifically in Greater Cairo, is the fine particulate matter carried by the winds from the rice fields in the Delta area to the urban areas of Greater Cairo.

In a field study by the Ministry of Housing and Ain Shams University in Egypt, the relationship between PM pollution and mortality rates was explored, and the same for sulfur dioxide. The study investigated the impact on cardiac and respiratory diseases in Egypt between 1995 and 2001. The study concluded a positive relationship between increased pollution with suspended particles and sulfur dioxide on one hand, and the high rate of mortality from cardiac and respiratory diseases on the other. A relationship was also found between smoke pollution rates and mortality from lung cancer.

Numerous scientific studies have also linked particle pollution exposure to a variety of problems, and predominantly respiratory and cardiovascular problems (EPA 2007; WHO 2005). The health impacts include:

- Increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example,
- Decreased lung function,
- Aggravated asthma,
- Development of chronic bronchitis,
- Irregular heartbeat
- Nonfatal heart attacks,
- Premature death in people with heart or lung disease.
5.2.3. Costs of Environmental Damage

Other direct and indirect impacts are such as damage to cultural heritage, damage to the ecosystem, shortened lifetime of machinery, impact on the working environment and workers’ performance, impact on tourism, and many other adverse direct and indirect impacts in addition to the adverse health impacts mentioned earlier and the deteriorated quality of life.

These environmental damages have been estimated to have a heavy impact on the economy. In a study by the World Bank (2003), the damage cost of environmental degradation in Egypt in 1999 was estimated to be LE 14.5 billion (USD 3.2 billion), or 4.8% of GDP. Urban air pollution was found to cause the largest damage costs, mainly due to the impacts on human health. The majority of the air pollution damage costs occur in Cairo, and are estimated to be of 1.5% of GDP alone.

In addition to this, health impacts of indoor air pollution in rural areas from biomass fuel use were estimated to be 0.33%. Another large contributor to the overall damage costs is waste management, which was found to have potential impacts on health from uncollected municipal waste, and industrial, hazardous, and health sector waste.

The health cost of air pollution from burning practices of household waste in Cairo was estimated to be 0.35% of GDP. As mentioned in Section 4.3, municipal solid waste consists of up to 60% organic material, and therefore a significant part of the air pollution problem can be linked to potential biomass resources available for better use.

Figure 1: Damage costs of different types of pollutants in Egypt in 1999 (Source: World Bank 2003, modified for illustration)

Figure 1 shows the relative contribution of air pollution in Egypt as compared to other pollution problems in terms of environmental damage costs. These figures are 1999 estimates, showing the mean values for the annual damage costs. This contrast is even expected to be larger if the estimates are calculated for the period of acute air pollution in Cairo during the black cloud episode.
5.3. **Legal Framework**

Since 1960’s, Egypt has adopted several environmental and environment related laws, decrees and regulations addressing various aspects of environmental protection and natural resources management. The most important of these include the Cleanliness Law No. 38 of 1967, Law No. 48 of 1982 which addresses the protection of the Nile River and its related waterways as well as Law No. 4 of 1994 for the Protection of the Environment.

5.3.1. **Law No.4 of 1994**

The enactment of the Environmental Protection Law No. 4 of 1994 addressed several significant legislative gaps in the legal framework for environmental protection neglected by the earlier sector laws such as water pollution and waste management laws, and it defined the mandates of the Egyptian Environmental Affairs Agency (EEAA) as the executive arm of the Ministry.

The main roles and responsibilities of EEAA include formulating environmental policies, preparing the necessary plans for environmental protection and environmental development projects, following up their implementation, and conducting pilot environmental projects (EEAA). The Agency is also the national authority in charge of promoting environmental relations between Egypt and other states, as well as regional and international organizations. Law No. 4 also established the Environmental Protection Fund (EPF) to fund various relevant environmental projects. The Fund is supported financially by the government, donors, and is sustained by fines paid by those violating environmental regulations.

5.3.2. **Environmental Impact Assessments**

The legal basis for environmental impact assessment (EIA) is established by the No. Law No. 4 of 1994. It is implemented through its Executive Regulations (Prime Ministerial Decree No. 338 of 1995). The Law and Regulations require an EIA for new projects and expansions and renovations of existing ones.

The Central EIA Department of the EEAA is responsible for supervising the screening process, managing the review of EIA reports, taking decisions on the acceptability of EIA reports and giving an opinion on the development and proposals for mitigation measures as provided in its mandates (EEAA 1995).

EEAA has also issued general EIA guidelines in 1995. These describe in detail the screening method, which is based on three lists of project types:

- White list projects with minor impacts (Category A)
- Gray list projects which may result in substantial environmental impacts (Category B)
- Black list projects for which complete EIA is mandatory due to the magnitude and nature of their potential impacts (Category C).

The category is determined by four factors: the type of activity performed by the establishment, the extent of natural resources exploitation, the location of the establishment, and the type of energy used to operate the establishment.

The guidelines include two screening forms, form A for white list projects and form B for grey list projects. For grey list projects, EEAA may require a scoped EIA, whose is specified by EEAA on the basis of the information presented by the developer in form B.
Haggar (2003) has conducted a review of the EIA requirements and its implementation, and he enlisted examples of projects under each of the three categories. It is found that most small-medium scale bioenergy systems serving multiple households would most likely fall under the grey list, whereas small-scale systems serving a single household such as a small biogas plant would fall under the white list, or be exempt altogether.

In observing the contents of the white and grey list forms provided by EEAA, it is notable that there are no requirements to assess social or socio-economic aspects of the project. However, it is required in black list projects, where in that case employment, relocation, culture, and gender, are few of the key words showing consideration of a wide variety of social aspects. Therefore, projects in the white and grey list are not subject to assessments or evaluations of their social impacts.

5.3.3. Environmental Law and Biomass

The environmental law of Egypt and its executive regulations has significant influence on the promotion of biomass handling from the aspects of solid waste management, GHG reduction, and regulations on air pollution, all of which are related to biomass production and handling in Egypt, although not explicitly mentioned in the provisions of the law.

In terms of solid waste management, the most specific stipulations of Law No. 4 relating to agricultural wastes is Article 37 of Law 4/1994 prohibiting the burning, disposal or treatment of solid waste except in designated areas far away from housing or industrial or agricultural areas as well as from waterways (Law No. 4/1994). Other provisions of the law mainly address municipal, industrial, and hospital wastes.

Regarding open burning of wastes, Article 38 of the Executive regulations provides that

“It shall be absolutely prohibited to openly burn the garbage and non-dangerous solid wastes. Throwing or treating the garbage and solid wastes shall be prohibited except in the places appropriated for the purpose away from the dwelling, industrial, and agricultural areas, and from the water courses, according to the specifications, regulators, and minimum limit of their remoteness from these areas...”

-Law No.4 Executive Regulations, 2005

Different treatment methods have been suggested in this provision, including methods involving energy recovery –see Annex 1.

As for ambient air pollution, the maximum limits of outside air pollutants as provided in the Executive Regulations of Law No.4 as shown in Table 5. These standards are within a reasonable range as compared to the World Health Organization (WHO) standards (WHO, 2002). However, as noted in the latest State of Environment Report of year 2005, these limits have been frequently exceeded whereas the open burning of both solid wastes and agricultural wastes together annually contribute to 42% of air pollution (MSEA, 2006). Other studies show that a greater contribution of agricultural wastes is notable during the acute air pollution episode of Greater Cairo in the autumn season.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Maximum Limit (µg/m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>0.05</td>
</tr>
<tr>
<td>NOx</td>
<td>0.05</td>
</tr>
<tr>
<td>SO2</td>
<td>0.05</td>
</tr>
<tr>
<td>Particles</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 5 Maximum limits for outdoor air pollution in Egypt (µg/m3) (Source: Law No.4/1994 Executive Regulations as updated in 2005)
<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Maximum Limit</th>
<th>Period Of Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur Dioxide</td>
<td>350</td>
<td>1 hr</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1 year</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>30 Milligram/M3</td>
<td>1 hr</td>
</tr>
<tr>
<td></td>
<td>10 Milligram/M3</td>
<td>8 hrs</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>400</td>
<td>1 hr</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>24 hrs</td>
</tr>
<tr>
<td>Ozone</td>
<td>200</td>
<td>1 hr</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td>8 hrs</td>
</tr>
<tr>
<td>Suspending Particles (Measured as black smoke)</td>
<td>150</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1 year</td>
</tr>
<tr>
<td>Total suspending particles</td>
<td>230</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>1 year</td>
</tr>
<tr>
<td>Chest Particles (PM 10)</td>
<td>150</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>1 year</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5</td>
<td>An average of 24 hours all over 1 year in the urban areas</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>An average of 24 hours all over 6 months in the industrial zones</td>
</tr>
</tbody>
</table>

### 5.4. National Program for Integrated Solid Waste Management

During 2000/2001, a national program for Integrated Solid Waste Management (ISWM) was initiated. The program relies on a close cooperation between concerned ministries and EEAA, both on the central and local government levels. It is based on the polluter-pays-principle.

The program focuses on the development of an enabling financial, institutional and legislative environment, to ensure the active participation of the private sector. Furthermore, it aims to promote decentralization of the management systems to independently work on waste minimization, waste recycling, and reuse, and building public awareness on the local levels.

The ISWM program addresses municipal, agricultural, healthcare, and construction and demolition wastes as a first priority, and industrial waste, waste generated from clearing of water and drainage canals, as well as municipal wastewater sludge, as second priority (EEAA 2007). This is carried out through 13 lines of actions composed of a fast track initiative for the clearing of solid waste accumulations, and long-term solutions addressing the roots of the problem, such as promoting recycling.

However, the center of attention has been municipal solid waste due to public pressure as a result of the direct impact on residents of urban and rural areas.

Within the framework of the national program for the Integrated Solid Waste Management, the National Strategy for Municipal Solid Waste, developed with support from the Egyptian Environmental Policy Program, finalized in 2001 and adopted by the Cabinet of Ministers (EEAA 2001). It sets the overall direction for municipal solid waste management in Egypt over a period of 10 years, laying down the principles for its implementation. Most actions were undertaken through official international development assistance, but mostly
5.5. **Support for Environmental Assessment and Management (SEAM)**

One of the international cooperation projects that significantly contributed to the understanding and promotion of improved solid waste and agricultural wastes handling in its studies of sustainable environmental management was the project of the Support for Environmental Assessment and Management (SEAM). SEAM was a two-phase project (1999-2004). Among the major outputs of the project was the development of the Governorates Environmental Action Plans (GEAPs) for Dakahleya, later replicated for other governorates, and the Solid Waste Management Strategy of Dakahleya (SEAM 2007). To ensure sustainability of project output, participatory monitoring was used to assess project performance and evaluate the environmental, social and economic impacts.

Dakahlia is the governorate in the Delta area in which about 25% of rice in Egypt is cultivated, which is most compared to other governorates (SEAM 1999a). Followed by Sharkia governorate, they are both the largest cultivators of rice in Egypt. SEAM project developed the Solid Waste Management Strategy of Dakahleya, which consisted of the following considerations:

- Solid waste characteristics and rates of generation
- Solid waste minimisation and segregation
- Temporary storage prior to collection (storage and transfer points)
- Collection and transportation
- Composting
- Final disposal
- Implications of the formal and informal reclaimation of reusable components of waste.

The notable difference between the outputs of this project and other similar initiatives in this field is that it was socially sensitive and it carefully considered and assessed different aspects of sustainable environmental management.

5.6. **Research and Development Initiatives**

In the survey for research and development initiatives in the field of bioenergy technology, it was evident that there is a limitation of budget for this purpose in most research institutes and heavy dependence on foreign cooperation and support rather than governmental or (local) private sector support. Furthermore, as explained earlier, most focus is on wind power and solar energy, which have been perceived as more convenient for international investors and welcomed by the national government.

Nevertheless, there are many initiatives and achievements that may nucleate this industry and provide a solid base if the efforts are well documented, shared, and synergized wisely and if awareness is raised at the government level about the benefits to socio-economic development and environmental sustainability. The main R&D efforts in the recent years related to bioenergy are as follows.
New and Renewable Energy Authority (NREA): NREA contributes in developing and localizing the manufacturing of components of biomass systems by participating or hosting pilot projects. The main projects in this field are:

- Developing a mobile briquetting system for plant residues in the field for use as fuel, starting since 2004. This project was conducted in cooperation the Academy of Scientific Research & Technology, and included developing a rural biomass-fuelled stove.
- Developing a Clean Small Carbonization System, in cooperation with US-Egypt Joint Science & Technology Board affiliated to Academy of Scientific Research & Technology, starting since 2004. It produces charcoal of high quality with low environmental impacts instead of that produced by traditional heavy polluting kilns by extracting the evolved gases and vapor during carbonization, separating and treating the liquid tars as liquid byproduct. Combustible gases could be used directly as a source of energy for the carbonization process.
- Conducting tests on the 25KW digester (1m3 capacity) installed in the NREA premises.

National Research Centre -Chemical Engineering and Pilot Plant Department: This department is dealing with different methods of treatments for increasing the value of agricultural residues including energy recovery methods:

- Development of improved rural stoves and ovens using agricultural residues.
- Pyrolysis-gasification of rice hulls,
- Gasification of agricultural residues for application as fuel (producer gas).
- Anaerobic fermentation of agricultural residues for production of gaseous fuel (biogas).
- Production of liquid fuel from agricultural residues by thermal treatment and anaerobic treatment (production of ethanol).
- Production of activated carbon from rice hulls.
- Production of bio-oil in pilot scale reactors (Tewfik, 2007)

Agriculture Research Institute -Institute of soil and water: This institute is conducting studies on recycling of agriculture residues for production of biogas and compost.

Ain Shams University: The mechanical department is conducting modest research on methods for combustion of agriculture residues for production of energy. Furthermore, Ain Shams University hosts the Environmental Research Institute for higher studies in environmental engineering and sciences of which some studies relate to management and utilization of biomass for renewable energy and its environmental impacts.

Cairo University Energy Research Centre (ERC): The most recent and most extensive research study of the RE industry in Egypt, including biomass energy, was that conducted by the ERC of Cairo University in a project for the Industrial Modernization Centre (IMC) in 2006 (ERC 2006). This study investigated the status of local manufacturing of RE technology components, the market situation, and scenario analysis for different policy choices for the MOEE to come out with a recommended strategy and action plan to achieve a strong sustainable national industrial program for the local market and export of RE equipment and components. One of the action plan components advised to develop a tailored R&D program in order to enhance capacity and competitiveness of industry to produce RE component export for foreign manufacturers of RE systems as well as the local
The bioenergy study included was led by a prominent environmental researcher in the field of bioenergy, Dr. El-Hinnawi, and it explained that R&D in bioenergy is mainly needed to improve stoves and energy devices used in traditional cottage industries considering local need and traditions, in addition to bioenergy devices such as gasifiers characterized by small capacity require local manufacturing to reduce costs and improve availability of spare parts and reliability of maintenance service. It is also stressed that demonstration projects of mature bioenergy technologies are needed before commercialization in order to stimulate public interest and their markets.

The American University in Cairo – Mechanical Engineering Department: This department has made many developments in the fields of solid wastes and biomass management including some studies related to use for bioenergy (El-Haggar 2007, El-Haggar et al, 2007). The latest related studies have included investigations of the variable parameters that can result in stable and durablesolid-fuel briquettes made from different agricultural wastes founding Egypt (residue size, moisture, chemical and physical characteristics) and studies promoting the development of eco-rural parks for rural development. This idea, emerging from the studies of Prof. Salah El-Haggar, a leading environmental researcher in Egypt, is not solely addressing the need for promoting renewable energy, but is mainly centered on the concept of sustainable management and recycling of solid waste and sewage in rural areas in all aspects. The proposed concept is an integrated system that produces animal fodder, biogas, briquetting, compacting, and composting in the same complex.

El Tabbin Institute for Higher Metallurgical Studies: This institute is equipped with moving laboratory for conducting research and measurements for air pollutants in the field. The institute conducted a recent experimental field study to add to and refine the best available information for the emission factor of rice straw burning applicable to Egypt.

NGOs: Several NGOs are participating in the development of alternative methods for utilizing biomass wastes and other solid wastes, among which recovery of energy is one of the options investigated. Most activities however, have been focusing on the methods of combustion and anaerobic fermentation for biogas, the traditional uses such as EL-Bassaisa Association, and Hans Seidel Stiftung Foundation demonstration projects, active in promoting biogas technology (Labib 2007, SIS 2005). Few projects have aimed to improve the upstream industry, biomass handling, by assisting in the development and promotion of briquetting systems such as the Association for the Protection of the Environment (APE), which has been active in R&D for biomass handling in cooperation with the academia (Haggar, 2007).

Foreseen regional center of excellence for RE in Egypt: The R&D efforts, whether for biomass technology in general or bioenergy specifically, have not yet been consolidated on a regional or national level, although to some limited extent in NREA. However, a promising development in this respect was announced in the latest environmental conference, Environment 2007. The Minister of Electricity and Energy and representatives of the German Embassy and the KfW development bank of Germany announced plans for establishing a regional center of excellence for RE for the Middle East and North Africa (MEDA) region established in Egypt with an allocated budget of 14 Million Euros (Environment 2007). This shows the prospects for rapid development of renewable energy in Egypt.
6. Biogasification Systems

Biogasification is the process by which solid biomass is converted into a combustible gas (product gas) in a thermochemical process. This gas is of low-to-medium heating value, typically around 5 MJ/Nm³. The product gas is a more convenient energy carrier and can then be used in burners for heating or in combustion engines or gas turbines for mechanical power and electricity generation.

The product, producer gas, consists primarily of carbon monoxide, hydrogen, carbon dioxide, and nitrogen, and has a heating value of 10 to 15 percent of the heating value of natural gas (Hinnawi 2006). This is used as town gas in many urban areas of developing countries, including India and China, whether from biomass or from coal.

A typical producer gas of biomass (wood) is composed of the following components (DGS 2005):

Non-combustible gases:
- Nitrogen (N2): 50%
- Carbon dioxide (CO2): 10%

Combustible gases:
- Carbon monoxide (CO): 20%
- Hydrogen (H2): 15%
- Methane (CH4): 5%

This is in addition to small percentages of light hydrocarbons, oxygen, solid particles, and condensable organic material (tar), as well as other elements particular to the process and feed material that may also be present.

However, there are many variations in the average contents of producer gas in the literature, as it is highly dependent on the technology and biomass used.

Technically the gasification of biomass is currently still in the demonstration and market-entry stages (DGS 2005). The development is currently directed towards generation of electricity and heat in advanced gas-turbine-based cogeneration units (Quaark et al. 1999). It also holds promising potential for widespread use in decentralized small-scale bioenergy plants.

6.1. Biogasification technologies

The design and operating characteristics of the gasifier system are determined by the intended use of the gas and the characteristics of the biomass fed in terms of size, texture and moisture content, among other parameters. Usually, the gasifier supplier will provide the specifications of the biomass to be used for optimal performance.

The main types of gasification systems that have been utilized to date are fixed bed reactors, fluidized-bed reactors, and entrained flow reactors. The systems also differ in
terms of the method of applying heat (weather from outside, or through partial oxidation of the fuel), the direction of fuel feeding and air supply, and the gasification medium used (air, oxygen, or steam).

Fixed bed gasification appears to be the most viable option for biomass based power generation for capacity up to 500 kW (Hinnawi 2005). Producer gas can then be used in power generating units. Combined Heat and Power (CHP) plants are the most promising method of using producer gas, and are feasible within their tolerance limits for tar compounds of 100mg/m³ of product gas (DGS 2005). However, in developing countries, small-scale application are more convenient.

An example of a small-scale gasifier design that has found quite wide acceptance is the rice husk gasifier of open-core design that originated in China. Beside rice husk gasifiers, several other gasifier models have also been developed. Presently, more than 700 gasification plants are operating in China (Hinnawi 2005). Furthermore, as a result of several promotional incentives and R&D support provided by the government, gasification technology has made significant progress in India in the recent years. About 1750 gasifier systems of various models were installed in the different parts of India. The total installed capacity of biomass gasifier system in India is estimated to be 34 MW (MNES, 2000). Small-scale applications can be defined to range from about 5 kg/hour up to about 500 kg/hour of biomass feed-rate, for which fixed-bed gasifiers are generally used (Hinnawi 2005). Fixed bed gasifiers are mainly of two types, the counter-current (updraft) fixed bed and the co-current (down draft) fixed bed.

6.1.1. Counter-current (updraft) fixed bed gasifiers

Counter-current (updraft) fixed bed gasifiers consist of a fixed bed of carbonaceous fuel (e.g. coal or biomass) where the fuel is fed from the top of the reactor and moves downward as a result of its conversion and removal of ashes. The air inlet is at the bottom and the gas leaves at the top. Therefore, the biomass moves counter to the gas flow and passes successively through drying, distillation, reduction, and hearth zones. Thermal efficiency is high as the gas exit temperatures are relatively low, and fuel with high moisture content (up to 60%) can be used (Quaak et. al, 1999). On the other hand, high amounts of tar and pyrolysis products exit with the gas, which is a disadvantage, unless the gas is used for direct heat applications in which tars are simply burned.

6.1.2. Co-current (down draft) fixed bed gasifiers

Co-current (down draft) fixed bed gasifiers are similar to the counter-current type, but the gasification agent gas flows in the same direction with the fuel. Heat needs to be added to the upper part of the bed, either by combusting small amounts of the fuel, or from external heat sources. Since all pyrolysis products pass through a hot bed of char in this configuration, tar levels are much lower than the counter-current type. This type is therefore more suitable in for use in engines. However, this type imposes limitation on moisture content of the fuel used (less than 25%) and also the exit gas tends to contain high amounts of ash and dust particles (Quaak et. al, 1999). A variant of this design is the open-core gasifier, which are especially designed to gasify fine materials with low bulk density such as rice straw, since no throat can be applied. In this design, fuel and air are inputted through the same wide inlet at the top of the reactor.
6.2. **Heat generation**

Using producer gas in heat application simply means that there is a distance created between the gasifier stage and the burner through pipes. At long distances such as distribution networks of town gas, tar condensation in gas pipes can be a problem. Another disadvantage is the loss of heat in the gasifier and piping as compared to direct combustion (DGS 2005).

In a technical paper issued by the World Bank, Quaak et. al. (1999) listed the advantages of this process compared to direct combustion of the fuel as follows:

- Low overall (gasification plus combustion) excess air factors, meaning relatively higher efficiencies.
- Low level of NO\textsubscript{x} emissions.
- Less fouling of the heat exchange equipment or heated products (in direct heat application such as drying or baking) as a result of fly ash in the combustion gases.
- Reduced indoor smoke and particulate matter levels leading to improved respiratory health in the case of household use.
- In the case of obligatory flue gas cleaning for environmental compliance, cleaning producer gas would be considerably cheaper than cleaning combustion flue gases, since the volume flow rate of producer gas is about 50% of that of combustion flue gases.

Since the typical producer gas has a heating value of about 5 MJ/Nm\textsuperscript{3}, i.e. about 12% of the heating value of natural gas, converted natural gas burners must be adjusted to consider the air-to-fuel ratio of producer gas (DGS 2005). Another factor affecting the end use of producer gas for heat is that the adiabatic flame temperature of producer gas is lower (1600\degree C) than that of natural gas (1900\degree C) (Quaark et. al., 1999).

6.3. **By-products and emissions**

The by-products of gasifiers are ashes, condensate, and unburnt carbon. The condensate consists mainly of water and low amounts of tar.

Treatment of producer gas involves cooling and cleaning of tars, alkali metals, and dust. This is even more important if used in a gas engine or turbine since tars may condense on valves and fittings and affect their performance. Furthermore, alkali metals, dust, and tars cause corrosion and erosion of cylinder walls and pistons.

Other emissions are the fumes during the flaring for start up and during shutdowns. The major emissions would be NO\textsubscript{x}, CO, SO\textsubscript{2}, and C\textsubscript{n}H\textsubscript{m}.

6.4. **Treatment and cleaning**

Tar removal can be done using air-cooled condensers, where tars are drained at the bottom of wide air-cooled pipes, or by spraying water in the gas stream with a venture scrubber. Also humidified packed belts can further effect condensation by increasing the cooling surface in a tar-condensing bed. In direct water-cooled tar removal systems, some of the dust, HCl, sulfur oxides, and possibly alkali metals are also removed by the water. This
however generates a tar-contaminated waste-water stream, which needs further treatment before disposal.

Tar cracking in a bed of char or a catalyst such as nickel or dolomite at high temperatures (600-1000°C) can be an alternative to the wet-gas cleaning systems. This process cracks the heavy tars in the producer gas into light, combustible gases that will not condense at the normal operating temperatures of a gas engine (Quaark et al. 1999).

Usually the condensate can be purified and discharged to the sewer system and the ashes into a normal landfill site unless containing high concentrations of toxic substances. With good quality biomass as feedstock, it is possible to use the resulting ashes as mulch. Some manufacturers extract the carbon, and it then has similar properties to activated carbon.

Dust-removal equipment for combustion flue gas such as cyclones, bag filters, and electrostatic precipitators can also be used for cleaning producer gas. However, bag filters may function poorly due to condensing tars (DGS 2005). Packed beds filled with granular particles such as sand, sawdust, and rice husks are also used for dust removal, and have the advantage of being an inexpensive solution.

The most common composition of a producer gas cleaning chain is a cyclone, followed by a tar condenser, a packed filter bed, and (optionally) a fabric filter (Quaark et al. 1999).

### 6.5. Economics of Biogasification

The aim of assessing the economic viability of gasification plants is to investigate the future costs of plants of different capacities considering the fuel prices and competing technologies, and considering the foreseen scenarios of electricity feed-in subsidies. The costs consist of capital, consumption, and operating costs.

- **Capital Costs:** The annual costs of the investment can be calculated using the net present value (NPV) method. With the NPV method, all expenditure and income arising from the investment is discounted at the total discounting rate, and also discounted to the present time (Olhoff 2006). The underlying interest rate and the amortization period must also be put into consideration. The discount rate is compared with the banks discount rate to show that the project is feasible compared to investing in a bank.

- **Consumption Costs:** These include auxiliary energy costs such as pumps and fuel handling systems etc, and fuel costs. Fuel costs depend on the supplier, the quantity purchased and its quality, and the season.

- **Operating Costs:** Mainly personnel and maintenance costs. The annual maintenance costs are usually assumed at a blanket rate of 10% of the investment costs, and other operation costs are also calculated as a percentage of the overall investment costs (DGS 2005).

Furthermore, the revenues and credits must be calculated. Most industrialized countries prescribe a minimum legal level of compensation for electricity produced from renewable energy (DGS 2005). This means the prices that can be charged or the credits that can be expected for electricity and/or heat.
7. Case Study: Biogasification in Egypt

Two gasification units for production of producer gas imported from China have been bought and operated by EEAA since 2003, with the objective of exploring alternative uses of rice straw. The plants are located in the two governorates that most generate rice straw in Egypt, Dakahlia and Sharkia governorates.

The two plants have now been under operation for 4 years, producing about 250m³/day of producer gas, providing to more than 100 families, which is yet below 40% of their capacities. They are considered demonstrational projects, and they have not yet been replicated due to several barriers that will be further discussed in this section. However, in terms of technical feasibility, it has proven feasible (Labib 2007).

First, a description of the existing biogasification project is presented, and finally an overview of the SD impacts of the project as compared to the BAU scenario is presented and discussed.

7.1. Description of the Biogasification plants

Both the plants in the governorates of Sharqia and Daqahlia are identical. The plant that was visited was the one closer to Cairo, the Sharqia plant. Sharqia is approx. 40 km away from Cairo and produces 875,000 tons of rice straw annually—see Table 4. The address of the plant is Sharqia Biogas. The plant is located in a rural residential area, and occupying 2.5 acres of fertile land—see Figure 2 and Figure 3. It delivers rice-straw derived producer gas to nearby households as a demonstration project currently serving 50 households with an average demand of 117 m³/day. The twin project in Daqahlia serves 57 households.

The employees are a team of 16, consisting of 1 manager, 2 agricultural engineers, 2 administrators, 6 workers (on a daily basis), and 5 technicians (Labib 2007).
Figure 3: Satellite image of Sharqia Biogasification Plant (Source: Google-Imagery, 2007, modified)
7.1.1. The process

The steps followed to produce and deliver the producer gas, starting from the rice straw delivery and ending at the stove at home have been explained in a tour lead by the plant operator during the visit to the plant in July 2007, listed as follows (see Annex 4):

1. Straw is supplied in compressed bales of the dimensions 0.4x0.6x1.2, and weight of 80Kg. The straw is mainly supplied by Queen Service Corporation (Armed Forces National Service). Currently, enough straw is stored on site for about 2 years of operation if demand is consistent.
2. Two storage locations for rice straw are in the site: one indoor (Figure 4) and one outdoor, together occupying approximately 1 acre.
3. Straw is manually fed into the Shredder—see Figure 5. It operates at a rate of 1 ton/hr, shredding to a size of 2-10 cm and uses the centrifugal force of the shredding process to thrust the shredded straw into a temporary storage room.
4. The shredded straw is temporarily stored in a small storage room of about 3x3m.
5. A screw conveyor draws the shredded straw from its storage room and feeds it into a downdraught fixed grate gasifier. The gasification is continuously controlled manually through an open port with adequate safety clothes and equipment—see Figure 6. This is done in shifts of two hours to reduce stress on the worker monitoring the feeding the gasifier.
6. In each charge, 1 – 1.3 tons of rice straw are fed over two hours.
7. The product gas enters into a series of flue gas cleaning/scrubbing stages enclosed in one unit—see Figure 7:
   i. Cyclone for ash removal.
   ii. Bubbling water sink for dust separation and cooling for tar condensation
   iii. Packed bed filter filled with corn cobs, followed by a water-cooled indirect contact condenser for removal of remaining tar.
8. A minor part of the gas stream exiting the gas cleaning system is diverted to a test flame, and a retrofit gas stove is also connected for demonstration and for staff use.
9. The product gas is pumped by a 5hp pump to charge a floating roof gas tank—see Figure 8.
10. The gas tank has a gas capacity of 350m³. The concept of the tank is to trap gas under a gas holder (inverted tank) floating on a partially filled water tank. The water volume in the tank is 500m³—see Figure 9. The gas volume is monitored manually by checking the marks on the floating roof.
11. Product gas is then distributed through underground polypropylene pipes to households for use in retrofit kitchen stoves—see Figure 10 and Figure 11. The current demand is 117 m³/day.
12. Wastes:
   i. Ashes are dumped in an outdoor ash pit, and manually sprayed with water to avoid fires—see Figure 12.
   ii. Tar is discharged to an outdoor sink with effluent water—see Figure 13.
   iii. Wastewater is discharged from two components:
      1. Direct-contact filter water 1.5m³/month is changed.
      2. Check-valve water: 1 m³/month is changed.
13. Other than solid and liquid wastes, there are emissions to the air. The possible sources of local air pollution are as follows:
   i. Fugitive product gas during feeding.
ii. Combustion emissions from the indoor test flame, and at the end-user.
iii. Gas leakages.

### 7.2. Comments by operators and end-users

The main problem in operating the plant according to the operators is the fluctuating demand, since low flow rate causes excessive tar depositing.

At the end-user side, through interviews (three interviewees) to learn about the social acceptance of the project, the following was noted:

- Recipients note that the flame is lower in temperature than with natural gas, therefore it takes more time to cook food. However, they believe that the food tastes better for that same reason, and the extra time is acceptable.
- Some mentioned “some noticeable smell during the first use, but gone afterwards” when first using the retrofit stoves on producer gas.
- Some inconvenience has been experienced due to tar clogging on the end-users’ side. This required maintenance to clean the equipment and piping at the household. It was however found acceptable, since the gas connection is however perceived as a step up from the previous methods of fuel use.
- They noted that for them the producer gas is more economical than LPG. They have not however considered that the pipeline connection was made for them (and all other families) for free for the purpose of demonstration as earlier mentioned by the Minister Advisor for Agriculture, Labib (2007), in an interview with him.
- The operators expressed interest in promotion of the project and in investigating alternative economic uses for the wastes produced, such as tar, which would create business and employment opportunities.

The method of interviewing end-users was however not systematic but rather a chosen sample household family. Therefore, a deeper more systematic study of the social acceptance and perception is necessary in order to gain a deeper understanding of the social and socioeconomic adaptation of the end-users.
FIGURE 4: INDOOR STORAGE LOCATION

FIGURE 5: SHREDDER

FIGURE 6: GASIFICATION UNIT

FIGURE 7: PRODUCT GAS CLEANING SYSTEM

FIGURE 8: PRODUCT GAS PUMP

FIGURE 9: GAS TANK
7.3. **SD Impacts of the projects in the case study - results**

The following assessment aims to briefly present quantitative and qualitative indicators of sustainable development impacts based on the assessment procedure undertaken in the NSS of Egypt for SDA and in reference to information collected in the field visits and interviews with end-users, plant operators, and the project managers – see Annex 3. However, a further breakdown to some indicators was added to facilitate evaluation.

In the evaluation of each impact, the definition of the indicator is presented as provided in the National Strategy (NSS 2002, and Olhoff et al, 2006), and the evaluation and discussion is based on information from interviews with stakeholders and field visits (see Annexes 2, 3, and 4).

7.4. **Economic**

7.4.1. **Infrastructure**

This indicator indicates whether the project will have the impact of replacing, expanding, or creating infrastructure.
The plan of the government to extend the natural gas networks is to reach the governorates and the Markaz (sub-governorates), but the villages are excluded. Currently the villages are phasing out their use of traditional rural stoves (Kanoon) and are switching to LPG for cooking. There are no national plans to connect rural villages to the natural gas networks. In the case of the villages of Sharqia, residents now use LPG for cooking. And for lighting, they already have access to electricity (Labib 2007).

In conclusion, the biogasification project had created new infrastructure.

### 7.4.2. Export Potential/Import substitution

This indicator indicates whether the project will have the impact of enhancing export potential or import substitution compared to the percentage of annual production.

None of the product gas is intended for export, and the product gas will replace the use of LPG, which is locally produced anyway. Therefore, there will be no export potential or import substitution. However, looking from a broader perspective, any saving in energy consumption is expected to free more of the local fossil fuel production for export (Barakat et al, 2003).

### 7.4.3. Payback period

This indicator indicates the economic impact of the project in terms of its payback period, to indicate its economic feasibility.

Accurate information about the economics of the project is not available since no feasibility study has been made on this demonstration project. However, the project has been found attractive to multiple potential private investors of multinational and national energy company since they are conducting investigations and feasibility studies on the biogasification plants (Labib 2007).

Despite lack of accurate estimations, the rough estimations of the EEAA show that the payback period is expected to be more than 15 years.

### 7.4.4. Energy Savings

This indicator indicates whether the project will have the impact of saving energy resources, measured in TOE as compared to the BAU scenario.

In the BAU scenario, the same energy consumption from LPG is expected, in addition to the open burning of rice straw. Therefore in the case of the project operation, the otherwise consumed amount of LPG is then displaced by rice straw. The displaced TOE as compared to the BAU scenario is therefore calculated as follows:

\[
TOE = \frac{\text{Rice Straw Consumption (t/yr)} \times \text{Heating Value of Rice Straw (GJ/t)}}{\text{Heating Value of Oil (GJ/t)}}
\]

Where rice straw consumption is 44.6 t$_{dry}$/year (as surveyed in the field visit), with a heating value of 15 GJ/t, and the heating value of oil is 42 GJ/t (BEC, 2007). The equation gives the result of 15.9 TOE of saved energy as compared to the BAU scenario.
Furthermore, energy saving is expected in the reduced truck transportation of LPG tanks in the BAU scenario, since the distribution truck will deliver to less clients as a result of the project (IPCC 1996).

### 7.4.5. State of technology

This indicator indicates whether the project will have the impact of promoting new technology in its implementation.

This biogasification technology, despite its simplicity, is the first to be introduced in Egypt, and the project therefore clearly promotes new technology in its implementation, and it inspires attempts to replicate and further develop it. In fact, multiple national and international energy companies are currently investigating means to utilize this technology profitably or to replicate it (Labib 2007).

### 7.5. Environmental

As explained in Section 3.2, the SD criteria for the environmental impact of projects assessed in Egypt only involves one indicator showing compliance with national and international environmental law; *The Improvement in Environmental Performance*. In the following evaluation of this indicator, qualitative analysis of different aspects of environmental sustainability have been listed in order to break down the indicator and to add any considerations that might be missing in the environmental law, such as GHG emissions reduction.

#### 7.5.1. The Improvement in environmental performance

**GHG Emissions reduction**

This sub-indicator evaluates the global impact of the project on reducing GHG emissions as compared to the BAU scenario.

There are two occasions where GHG emission reductions are achieved. First, due to the displacement of the otherwise used fossil fuel (natural gas or LPG) in the BAU scenario. And second, the reduction of open burning, which, due to incomplete combustion, open burning causes a net increase of GHG emissions.

**Avoided Open Burning**

The contribution of Nitrous Oxides (N₂O) and Methane (CH₄) are calculated using their Global warming potential (GWP) to obtain the CO₂-equivalent (CO₂e). GWP is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming as compared to CO₂, which has a GWP of 1.

Over the span of 100 years, Methane (CH₄) has a GWP of 23 and Nitrous Oxide has a GWP of 296 (IPCC 2001).

<table>
<thead>
<tr>
<th>Trace Gas</th>
<th>Emission Ratio</th>
<th>N-C ratio</th>
<th>Molecular Weight ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄</td>
<td>0.005</td>
<td>16/12</td>
<td></td>
</tr>
<tr>
<td>N₂O</td>
<td>0.007</td>
<td>0.014</td>
<td>44/28</td>
</tr>
</tbody>
</table>
In Table 6 above, the Emission Ratio (ER) for CH₄ is relative to the total carbon released, while the ER for N₂O is relative to the total nitrogen release.

In order to calculate the total amount of carbon burnt, the following input data is used as suggested in the IPCC (1996) guidelines, whereas the values are obtained from the best available sources have been used as provided in the table with the respective source:

**Table 7:** Data needed to calculate total carbon release

<table>
<thead>
<tr>
<th>Input Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter content</td>
<td>0.92ᵃ</td>
</tr>
<tr>
<td>Fraction Oxidized</td>
<td>0.9ᵇ</td>
</tr>
<tr>
<td>Carbon Content</td>
<td>45%ᶜ</td>
</tr>
</tbody>
</table>

ᵃ: Ebeid, 2007  
ᵇ: A default value of 0.9 can be used if national values are not available, this accounts for the approximate 10% of carbon that remains on the ground as a result of charcoal formation and other aspects of incomplete combustion (Seiler and Crutzen, 1980; and Crutzen and Andreae, 1990).  

The total carbon release can be calculated as follows:

\[
\text{Total carbon released (t)} = \text{Amount of Rice Straw left for Burning} \times \frac{\text{Dry matter content of the rice straw (t}_{\text{dry matter}}/\text{t}_{\text{biomass}})}{\times} \ \frac{\text{Fraction oxidized}}{\text{Carbon content (t}_{\text{carbon}}/\text{t}_{\text{dry matter}})}
\]

Using the input data from Table 7, and given that the quantity of rice straw is 44.6 t/yr, the total carbon released according to the equation above would be 16.6 tons/yr.

Using the input data from Table 6, the trace gas emissions can be calculated as shown in the following equations:

\[
\begin{align*}
\text{CH}_4 \text{ Emissions [t]} &= \text{Carbon Released [t]} \times \text{Emission Ratio} \times 16/12 \\
\text{N}_2\text{O} \text{ Emissions [t]} &= \text{Carbon Released [t]} \times \text{N/C Ratio} \times \text{Emission Ratio} \times 44/28
\end{align*}
\]

And accordingly,

\[
\begin{align*}
\text{CH}_4 \text{ Emissions [t]} &= 16.6 \times 0.005 \times 16/12 = 0.11 \ t_{\text{CH}_4} \\
\text{N}_2\text{O} \text{ Emissions [t]} &= 16.6 \times 0.014 \times 0.007 \times 44/28 = 0.00256 \ t_{\text{N}_2\text{O}}
\end{align*}
\]

These are the emissions that would have been released over one year in the absence of the biogasification plants.

The total CO₂ equivalent (CO₂e) is therefore as follows (IPCC 1996):

\[
\text{CO}_2\text{e} = \text{ton}_{\text{CH}_4} \times \text{GWP}_{\text{CH}_4} + \text{ton}_{\text{N}_2\text{O}} \times \text{GWP}_{\text{N}_2\text{O}}
\]
And accordingly,

$$\text{CO}_2\text{e} = 0.11 \times 23 + 0.00256 \times 296 = 3.29 \text{ tons CO}_2\text{e/year}$$

Therefore, the project has reduced GHG emissions of the equivalent of 3.29 tons of CO2/year due to the avoided N2O and CH4 emissions of open burning.

**Avoided Fossil Fuel Combustion**

As for the displaced LPG compare to the BAU scenario, CO2, CH4, and N2O emissions are all produced during LPG combustion. Although the formation of CO acts to reduce CO2 emissions, the amount of CO produced is insignificant compared to the amount of CO2 produced. Also, nearly all of the fuel carbon (99.5 percent) in LPG is converted to CO2 during the combustion process. This conversion is relatively independent of firing configuration (EPA 1996). The carbon emission factor for LPG of 17.2 tC/TJ (IPCC 1996).

Given that the current demand at 250m³/day of product gas with the energy content of 5MJ/Nm³, the total energy consumption displaced over a year is 456.2 GJ for both plants as compared to the BAU scenario. This results in 7.85 tC/yr, which translates to approximately 28.8 tCO2 using the following formula:

\[
\text{Displaced Energy Demand [TJ]} \times \text{LPG Carbon Emission factor [tC/TJ]} \times \frac{\text{Relative Weight of CO2 [MWco2/MWc]}}{}
\]

Furthermore, more GHG reduction is expected due to the reduced truck transportation of LPG tanks in the BAU scenario, since the distribution truck will deliver to fewer clients as a result of the project. This can be relatively balanced by the additional GHG emissions from transporting rice straw to the site, which might even outweigh the reduction of GHG emissions in avoided LPG transportation since rice straw has a much lower energy-density, and therefore, more transportation is generally needed (IPCC 1996).

**Local air quality**

This sub-indicator evaluates the impact of the project on local air quality, estimating the emission load, such as total tons of SOx, NOx, and particulate matter emitted or reduced. In the business as usual scenario, most concern is over the PM emissions from the open burning of rice straw. In the latest experimental study of Ebeid (2007) attempting to estimate the national emission factor for open burning of rice straw in Egypt, the emission factor for total suspended particles (TSP) was found to be approximately 10 Kg/ton of dry rice straw, of which finer particles are widely dispersed and contaminated the air on the local and regional scale. On the other hand, in biogasification, particulate matter emitted is negligible if any. This is due to the producer gas cleaning train, and there are no exhaust gas emissions in this process, this is confirmed by measurements showing fugitive emissions are below the legal limits of Environmental Law 4/1994 (Annex 2). Therefore, the local air quality is improved as a result of the project.
Indoor air quality
Due to the nature of this project, this sub-indicator was added in the breakdown to indicate the impact of the project on indoor air quality in the workplace and at the end-user.

Measurements of emissions in the workplace were conducted by EEAA to confirm compliance with environmental law requirements. The measurements were conducted for SO₂, CO, and NOₓ at two locations, next to the gasifier unit, and next to a typical stove operating using the producer gas, representing the typical end-use.

The measurements confirmed that the emissions from the production and the end use in the workplace and from the end-use have shown compliance with the requirements of Law No.4/1994 and its executive regulations – see Annex 2. The measured emissions can be attributed to the expected fugitive emissions mainly from the biogasification unit during fuel feeding.

Furthermore, on the end users side, as mentioned in Section 4.6, biomass is still used in about 17% of rural households and remote areas for heating (cooking) purposes. Therefore, like the introduction of LPG, the provision of renewable town gas as in this project would replace harmful technologies that are known to cause respiratory diseases and other negative health impacts (Quaak et. al, 1999).

Water Quantity and Quality
This sub-indicator evaluates the impact of the project on water quantity and quality if any.

The waste water is heavily tar-contaminated, and is contaminated with contaminants absorbed from the gas stream such as HCl, sulfur oxides, dust, and possibly alkali metals. Currently the waste water disposal is outsourced to a company operating in compliance to the regulations of Law 4/1994.

Soil condition
This sub-indicator evaluates the impact of the project on soil condition in terms of quality and quantity, such as soil pollution, erosion, and the extent of land use changes.

As mentioned previously, the waste water is outsourced to a company operating in compliance to the regulations of the environmental law. The remaining ash and char is spread in the nearby agricultural lands, which is not restricted by Egyptian law.

Biodiversity
This sub-indicator evaluates the impact of the project on any natural habitats and species whether by destruction or alteration.

This area is a growing rural village with small industrial activities established in the outskirts. Therefore, in the absence of the project, this area would have been exploited for residential or industrial activities due to its proximity to the growing agglomerate of residences and small industries, despite being fertile land. This implies that the land would have been exploited to alter its natural state to a larger extent in the BAU scenario, and therefore likely to have
greater impact on the ecosystem and biodiversity due to the smaller environmental footprint of the biogasification plants.

7.6. Social

The sole indicator used in the NSS of Egypt to evaluate the social aspect is the impact on Employment, a national priority far ahead of any other social criteria.

7.6.1. Employment

This indicator evaluates the qualification requirements, whether high or poor qualifications, and security of the job, whether temporary or permanent.

In each plant, there are 16 employees: 1 manager, 2 agricultural engineers, 2 administrators, and 5 technicians, all with long-term contracts, in addition to 6 workers with a daily contract. Furthermore, the collection, baling, and delivery of rice straw require further manpower. This demonstrates that the biogasification project created quality employment opportunities for the local community.

However, it must also be considered that similar numbers of employment opportunities could have been possible in the absence of the project in the BAU scenario of expanding exploitation of land. Furthermore, there is also a possibility of job losses, or reduced demand, in the LPG tanks distribution services as compared to BAU.

Another possible negative impact on employment is the displaced use of rice straw in the composting industry and fodder production which exists in both governorates. However, the rice straw used for the biogasification plants are surplus residues that would have otherwise been burnt in the open field since the capacity of alternative uses have not yet reached the target needed to absorb all rice straw residue (Labib 2007). Therefore, in the case of the extensive duplication or expansion of this project, this possible impact must be taken into consideration.

7.7. Criteria from International Investors’ View

7.7.1. Profitability

This indicator shows the extent of return on investment (ROI), where a high ROI would be 6% or higher. However, this indicator is not calculated in this study due to the lack of sufficient data, given that the projects have been established as demonstration projects and built without a feasibility study and a market study. However, EEAA estimates suggest that the payback period of the project would far exceed 15 years, and therefore likely have an ROI less than 6%. Furthermore, estimates of manufacturing the system components in Egypt showed costs that are more than double of those achieved in China (Labib 2007).

7.7.2. Investor Image

This indicator reflects the image that this project would give to an investor, whether negative or positive. In the case of a biogasification plant, given that it is a renewable and sustainable energy system that reduces CO₂ emissions, such a project is immediately associated with
environmental awareness and corporate-social responsibility. Furthermore, given the concern of the media over alternative uses for rice straw, involvement in such a project is expected to receive significant appreciation from the media for the contribution to local air pollution prevention.

7.7.3. Project risk
This indicator specifically indicates the probability of the generation of expected emission reduction, in the form of Certificates of Emission Reductions (CERs), as a result of the project, to show its liability to profit as a CDM project with marketable GHG emission reductions.

According to the CDM Guidebook issued by UNEP (2004), there are three types of acknowledged small-scale CDM projects for which modalities and procedures have been established. These types are renewable energy projects, energy efficiency improvement projects, and other small-scale project that reduce anthropogenic GHG emissions. Under the type of renewable energy projects is the category of Thermal energy for the user. The standard methodology for CDM certification is now already established under the name AMS-I.C.: Thermal energy for the user with or without electricity validated very recently, August 2007 (UNFCCC 2007). This methodology applies to renewable energy project activities for thermal energy with an output capacity less than or equal to 15 MW such as that for rice straw gasification. The limit of 15 MW refers to the rated capacity (UNEP 2004, UNFCCC 2007). Therefore, since the project satisfies the condition of additionality, it would be approved as a CDM project with acceptable CERs.

8. Discussion

1. The research results showed the current practices related to sustainable development assessment in Egypt and related regulations, the status of the bioenergy industry in Egypt in different aspects, the stakeholders, and the relation to sustainable development. This relation was then emphasized through the study of the relation of biomass to one of the critical environmental problem of air pollution as an example of a potential synergy. Finally a case study of biogasification technology, in Egypt was investigated in order to elaborate on the practical aspects of promoting bioenergy for sustainable development and the challenges faced. The positive and negative sustainable development impacts of the case study were qualitatively and quantitatively presented using the MCA framework for SDA with further indicators added for elaboration.

2. In the first stage of the research investigating SDA practices in Egypt that may apply to bioenergy projects, it was quickly realized that all new RE projects are conducted under the framework of the CDM, under which many guidelines have been set to recommend best available SDA methodologies. It has been noted that under international capacity development programs (UNEP CD4CDM) Egypt has conducted a National Strategy Study (NSS) using MCA as an SDA tool for the initial screening of projects to be prioritized in the promotion of CDM projects, but such practice has not been adopted and practiced later, and this study has been made in 2002, and the reporting was presented in English language. These observations
indicate that there is a great need to further enhance the national ownership of environmental planning.

3. Among the stakeholders participating was the Designated National Authority (DNA) who is required to approve and promote CDM projects on behalf of the government based on fulfillment of eligibility criteria and advisably conduct SDAs. However, as explained in Section 3.2, the mere provision of an approved EIA by the CDM project applicant would meet the DNA’s requirements for approval. Keeping that in mind, and noting that in Section 5.3.3 it is explained how project are subject to classification into three categories, of which two do not include consideration of social aspects, it can be concluded that the social impacts of bioenergy projects (mostly classified in the grey or white list) are not accounted for when processing project applications. Therefore, more can be done on the side of the Egyptian government to ensure that the promotion of renewable energy projects in Egypt takes into account the positive and negative social impacts of the projects such as for poverty alleviation, distributional equity, access to clean and affordable services, security of energy supply, etc. This in turn is likely to enhance the contrast between bioenergy technology and other technologies receiving more attention in Egypt as indicated in Section 4.1.

4. Perhaps this lack of concern over social aspects in the promotion of RE in Egypt is a result of the high prioritization of projects that invite foreign investments as indicated in the excessive weight allocation chosen for the indicators for “attractiveness” to investors set in the SD criteria during the NSS as demonstrated in Section 3.2.1. It can be interpreted as an imbalanced weight allocation reflecting national priorities. Another likely reason is the lack of national capacity to conduct such assessment studies independently to ensure that each project “is voluntary, satisfies additionality criteria, satisfies national criteria, and contributes to national sustainable development” as provided in the mandates of the DNA as explained in Section 3.2.4. Institutional capacity building is therefore necessary in this respect, with aid of national initiatives to ensure sustainability, such as national research institutes and other stakeholders.

5. The energy industry in Egypt as explained in Section 4.1 is highly centralized and favors large-scale grid-connected projects. This might explain the success of wind farms and large solar-thermal power plants over bioenergy projects. However, with the establishment of the Supreme Council of Energy in 2006 and its agenda to issue a new electricity act for RE, it is expected that smaller-scale projects be more easily promoted by the government and recognized as an engine for sustainable rural development such as proven in India and China among many other countries. Furthermore, very recently, in August 2007, CDM certification for small-scale projects such as for rural bioenergy systems has been established under the name AMS-I.C.: (Small-scale) Thermal energy for the user with or without electricity as noted in Section 7.7.3. This shows promises of increased recognition of such projects on the international level as well.

6. Through the research on the status of bioenergy technology, much information about barriers to their development was collected, which hopefully would be partially addressed by the new electricity act promoting RE, although its details have not been disclosed yet. The status today shows very limited development mainly due to lack of
incentives. However, even in the case of financially supported projects, other problems arise. This is apparent in the example biogas plants mostly financed by GEF Small Grants Program and other donor assistance, where out of 850 household plants constructed, up to 80% of the plants are not operating today because of a series of technical problems and lack of local expertise and supporting follow-up services among other limitations. This shows that the success of bioenergy projects extends beyond the economic/financial barrier. Therefore, given the financial support, much attention should still be paid to the technical barriers, awareness and information barriers, market barriers, and institutional and policy barriers that must be addressed in parallel.

7. Since the latest and most extensive study for the bioenergy systems was carried out by the Energy Research Center of Cairo University in 2006 for the Industrial Modernization Center as partly summarized in Section 4.7 for policy makers, it is expected that new RE policies would adopt the recommendations concluded in the research to consider economic incentives, market tools, and promotional R&D activity. These recommendations can be summarized into the following key-words: financial and market incentives, decentralization of the energy market, and localizing components of the industry.

8. Another recent study by the UNEP also called for change in RE policies stressing on the importance of public participation in the case of RE as compared to older policies that were convenient for conventional energy sources, such as NG and oil, which focused on the supply side of the energy chain.

9. In the studies about the bioenergy industry in Egypt, little or none has been mentioned to elaborate on local environmental benefits and benefits to the local community, and no attempts were made to link environmental costs of pollution to the importance of bioenergy projects that shall absorb abundant resources of biomass that are otherwise wasted and causing different types of pollution, of which air pollution is the most felt impact.

10. Compared to other renewable energies emerging in Egypt, namely Solar and Wind Energy, it is notable that small-scale bioenergy is the type that has proven most promising to be completely locally produced due to its simplicity and availability of the components already in Egypt. This shows the ease of adopting bioenergy technologies once appropriate policies and other barriers are removed to promote small-scale RE technologies.

11. A major driving force that should be incorporated in the assessment of the feasibility of biomass projects is the impact of wasted biomass on air pollution, where 15 million tons of municipal solid waste is generated annually in Egypt of which up to 60% is organic material, and also up to 35 million tons of agricultural wastes are generated annually. Open burning of rice straw alone is estimated to contribute to 42% of acute air pollution episode of the “black cloud” every autumn since the harvest and open burning period coincides with the period of atmospheric stability, while rice cultivation is all located upwind from Greater Cairo. This demonstrated the strong link between potential biomass resources and one of the critical environmental problems in Egypt, and it also indicates the large amounts of potential biomass energy wasted, along with many potential local development opportunities that would come
with the exploitation of this potential into bioenergy industries. Therefore the synergy has been elaborated in the results of the research, which would not be found in wind and solar energy that contribute less to solving local environmental problems.

12. Looking up the chain of the potential bioenergy industry, many efforts have been made that would provide a convenient platform for the success of bioenergy projects by the improved management of the biomass resources to be more readily available for interested users. These efforts are the ones for solid waste management and agricultural waste management, such as compaction, collection, and storage. These initiatives by the EEAA and other concerned stakeholders have aimed to collect agricultural wastes for the purpose of avoiding open burning, and the result is an abundance of collected biomass without sufficient established projects to utilize these quantities. Therefore, there is abundant surplus biomass, readily available, and yet to be utilized without affecting or displacing other beneficial uses.

13. Significant initiatives that have driven the management of solid wastes and agricultural wastes have been such as the National Program for Integrated Solid Waste Management and supporting projects such as the SEAM project as mentioned in Sections 5.4 and 5.5. Solid waste management, another major environmental problem in Egypt is directly linked to the development of biomass resources management, and therefore must be considered in the status of the bioenergy industry in Egypt and its potential. This also demonstrates the synergy in solving other pollution problems together with air pollution and GHG emission reductions, while other solid waste-related industries develop and job opportunities emerge.

14. Furthermore, the technical capacity to adopt new technologies is available, although modest. As shown in Section 5.6., there have been many initiatives and ongoing efforts in different fields of bioenergy for demonstrational purposes and for research and development, and the status of the technology as explained in Section 4.6 shows what can be interpreted as the seeds of this industry. However, it is apparent that there is no one entity that it is managing and promoting the bioenergy industry despite the abundant resources and large potential foreseen for this industry. Although the New and Renewable Energy Authority (NREA) is responsible, it has conducted limited development in this field due to limited resources and high dependence on donor assisted projects. Therefore there is a pressing need to consolidate efforts in this field on a national scale to have a common plan and agenda.

15. One promising initiative to consolidate efforts in this field is the planned regional center of excellence for RE to be established in Egypt for the Middle East. In order to ensure sustainability and conformance with national socio-economic development and local environmental sustainability, it is necessary to ensure a high degree of participation of local experts and national authorities in the planning of this center of excellence and in the implementation and management.

16. It was shown in Section 5.2 that bioenergy projects utilizing agricultural waste would have a positive impact on the global GHG balance due to the avoidance of non-CO2 GHG emissions of uncontrolled open burning, in addition to the displaced fossil fuels otherwise used in a BAU scenario. This also qualifies such projects to apply as a CDM project since they satisfy the additionality criteria of CDM eligibility. On the
local scale, positive environmental impacts have been demonstrated with focus on impact on local air pollution.

17. However, this research has focused on a biomass type that is otherwise wasted and causing an environmental pressure, which is an ideal case in the promotion of bioenergy. So rice straw might not be a representative example of foreseen biomass fuels to be used in the future. In reality, there are many other types of biomass types that may have a more elaborate negative impact on the environment that must be addressed. As mentioned in Section 4.3, some of the biomass resources found in Egypt are such as dung, which may cause indoor air pollution in some uses, or energy crops such as Jatropha, which raises concerns over the concept of cultivating crops for the sole purpose of energy use, such as excessive use of chemical fertilizers, or displacement of food-crops otherwise cultivated on the fertile land, etc. Therefore, although the focus of the research is on an ideal opportunity for benefiting from bioenergy, it is not representative of different types of biomass, and different technologies used. This shows that a closer look at the local conditions is necessary in order to identify the optimal uses of certain RE technologies or certain biomass types without generalizing the developmental impacts of bioenergy.

18. Existing policies have shown otherwise, where decisions where made based on analysis of the bioenergy as an entire sector such as in the National Strategy Study as explained in Section 3.2. It seems that all biomass types and bioenergy technologies have been grouped under one sector, such as done with solar power and with wind power, which do not have the similar diverse and multifaceted nature of bioenergy projects. Furthermore, the study did not propose a mechanism to monitor the progress of proposed ideas since 2002 and to ensure the validity of the assumptions used in the study. This follow-up activity would have reflected the national concern over national priorities, since the original study was only conducted under foreign initiative. One of the results of this is that the DNA shows very limited activity in directing the progress of CDM projects towards the national development and environmental development agenda by merely approving projects based on meeting the procedural requirement of an approved EIA. Furthermore, the EIA of many projects can be classified as a Category A or B (white and grey list) which only consider impacts on the ecosystem with no regard to social aspects as explained in Section 5.3.2. This is of special concern to small-scale energy projects that are expected to rapidly develop in the future with the increased availability of standard methodologies for small-scale projects and also in the case where project developers would alternatively use the bundling method of small-scale projects into one large CDM project.

19. One solution to such a gap in national supervision over the development of the RE sector and other CDM projects can be to incorporate strategic environmental impact assessments in the environmental planning process of local authorities. This would assess the social, socio-economic, and environmental impacts of projects, programs, and policies within the context of the national development agenda and forecasts, and with consideration of externalities, in order to give a real indication of costs entailed in a larger scope, not only on investors’ budgets.

20. Section 5.2.3 showed an indication of the magnitude of environmental damage cost of air pollution and open burning of solid wastes and agricultural residues, which, along with other emissions from the energy industry, have the highest contribution to total
environmental damage costs. Much of the air pollution is attributed to malpractices in handling solid wasted and agriculture residue that are wasted by burning in the open. This translation into numbers shows a significant potential to persuade policy-makers to promote certain bioenergy technologies that would provide alternative uses of the wasted resources and simultaneously mitigate the impacts of open burning. Taking externalities into account will therefore improve the perceived economic feasibility of many bioenergy projects from a strategic perspective. Such an approach would better justify the need to adopt policies that feature market tools and economic incentives such as suggested in Section 4.7. This would support such projects as the biogasification demonstrational projects investigated in the case study.

21. Section 6 introduced the theoretical background for the case study where an emerging bioenergy technology can be evaluated from the different angles of sustainability. It was noted that the chosen technology, biogasification, is old and has been technically proven before in periods of fuel-scarcity, either for uses in power generation or for heat. From the environmental point of view it was clear that biogasification for thermal uses is more environmentally friendly than combustion technologies in many aspects, despite the generation of tar and wasted char as explained in Sections 6.2 and 6.3. In Section 6.5, the typical method for studying the economics of biogasification projects was presented, and it can be seen that promotional policies from the government can play a role in reducing the capital and consumption costs, and increasing or securing the revenues for an investor. However, in the BAU scenario, as explained later, the plants are far from being economically feasible from the perspective of conventional/classical economics.

22. The various sustainable development impacts where evaluated in the context of the case study of the identical demonstration plants in Sharqia and Daqahlia governorates, following the field visit to Sharqia plant. The case study demonstrated how most of the sustainable development impacts show positive indication from the environmental perspective and the social perspective. However, in the Economic and investment-related indicators as enlisted in the NSS MCA methodology of Egypt, the project showed little economic viability. It is essential to note that in the indicators chosen for the economic aspects of the SD impacts according to national priorities have not included any consideration for externalities. This might be due to the assumption that environmental impacts are already taken into account in the Environmental criteria indicators, which have a much lower allocated weight. Therefore, an indicator involving a cost benefit analysis would reduce the bias of the set of indicators. This is not likely to cause duplication (double counting) in assessing environmental impacts, since the environmental indicators in the NSS have only taken into account compliance with law.

23. Throughout the research, there was a notable considerable lack of information to assess impacts from a Life Cycle perspective. In order to correctly assess and compare the SD impact of projects such information must be available. This would take into consideration all the upstream and downstream processes and material and energy flows throughout the bioenergy system, which would identify various indirect impacts such as those resulting from biomass collection and delivery, and waste disposal, impact on other systems, etc, and the entailed social and economic impacts.
24. Another limitation to the validity of the economic aspects of the SDA is that the assessment is in the context of the current policy mix. The present policies have little incentives and market tools for RE and furthermore heavily subsidize the competing non-renewable fuels. Therefore it can be foreseen that this assessment would show more positive results in the context of new policies and programs promoting RE. This development, as explained in Section 4.1., is expected in the near future.

25. A major notable gap in the indicators used in the SDA is in the consideration of land-use and a land-use change, since the biogasification plants or any other rural bioenergy projects are most likely to be built on fertile agricultural lands near to the biomass resources. This implies damage to fertile land and reduction of cultivated areas. This is a major limitation to the duplication of many bioenergy projects since project developers would either need to pay a very high cost for the agricultural land near the resources, or otherwise pay a high cost for transportation services to the alternative location in a remote area.

26. For the local community, the development of the biogasification projects was met with a positive attitude, since the major concern is over costs (currently supported by EEAA) and convenience of the technology as compared with previous alternatives, and there is a willingness to further develop this system with local initiative.

9. Conclusion

1. The research findings generally showed that there is a large potential and a pressing need to develop the bioenergy industry in Egypt for environmental sustainability and development. The positive environmental and social impacts may outweigh negative impacts that can be mitigated, but this is not adequately assessed. Currently, the screening process for RE projects only considers compliance to national law, which shows little consideration to social impacts and strategic benefits, and there is little active practice of guiding project development towards the national development priorities.

2. In order to achieve improved environmental planning to ensure the outcome referred to above, more of the initiatives in this field must come from the stakeholders, mainly the national authorities, rather than through the usual foreign assistance. Ownership of the national agenda is essential.

3. The research showed that despite the high costs of some energy projects, the consideration of externalities would better express the true feasibility of bioenergy projects from a strategic perspective. This indicator is therefore needed in order to give a more considerate indication of the impact of any project on the economy as a whole with consideration of environmental damage and health impacts. Air pollution from open burning showed the highest environmental burden on the economy.

4. Given that open burning of agricultural and municipal wastes contribute to 42% of annual air pollution, certain bioenergy projects can therefore have a significant influence on improving local air quality and reducing solid wastes problems, while saving energy, and reducing GHG gases thus qualifying as CDM projects. This synergy has been explained in this research, and further elaborated in the context of the biogasification plants case study.
5. Biomass resources in Egypt are abundant in the form of organic-rich solid wastes and agriculture residue. The management of these resources is undergoing rapid development in response to severe air pollution caused by open burning, in addition to other impacts of municipal solid waste. However, as one of the recipients of this resource, the bioenergy industry is not sufficiently developed yet to receive this abundance, which is also far from being absorbed by other alternative biomass uses such as compost. Most initiatives in this respect are scattered and need to be consolidated.

6. There is an expected change in energy policies to promote RE technologies with market tools and economic incentives, while subsidies on competing fossil fuels are also being rationalized. Therefore, the economics of bioenergy systems will rapidly improve, but other barriers must be overcome, such as the limited technical capacity or lack of market information.

7. The outcome of this research emphasizes that significant potential positive impact of certain bioenergy systems on the local sustainable development is foreseeable, and there is an expected national and international support to further promote bioenergy and provide a level playing field with other energy sources. The message conveyed is that through proactive environmental planning and management, many synergies in development can be achieved, and they will only be sustainable if the initiatives stem from the host. Bioenergy technology has shown to be one of these promising synergies, and is foreseen to rapidly develop and grow in the near future.

10. **Recommendations:**

Following the discussion and conclusions and experiences during the research for this study, the following recommendations are suggested:

1. On the international level, the capacity building projects made for Designated National Authorities for CDM projects must be monitored on the long term to ensure that the correct practices to which they are mandated are actually followed in practice.
2. On the national level, effective ownership of the national agenda for bioenergy and CDM projects must be enhanced, which can be described as “proactive hosting”.
3. Stakeholders in the host country must consolidate efforts to promote bioenergy systems and direct it towards sustainable development needs.
4. For all stakeholders, planning for widespread use of bioenergy is recommended in preparation for the expansion of bioenergy systems in Egypt due to the emerging favoring conditions that are expected to rapidly promote small-scale as much as large scale bioenergy systems.
11. References

1. **AWRU (2005):** *Agricultural Waste in Egypt*, PowerPoint Presentation on February 2005, Agricultural Waste Recycling Unit (AWRU), Ministry of State for Environmental Affairs (MSEA), Egyptian Environmental Affairs Agency (EEAA), Presented on the work-group meeting of the Regional Environmental Management Improvement Project (REMIP) of the Japan International Cooperation Agency (JICA).


10. **Eberhard, Anton; Gratwick, Katharine (2005);** *The Egyptian IPP Experience: From state to market and back again: Egypt's experiment with independent power projects*. Management Programme in Infrastructure Reform and Regulation, Graduate School of Business, University of Cape Town, Breakwater Campus, Private Bag, Rondebosch 7701, Cape Town, South Africa. Available online 7 July 2006


18. **El-Haggar, Salah M (2007):** Personal Interview with Prof. Salah El-Haggar, Professor of Energy and Environment, American University in Cairo (AUC), June 2007


27. **GCRBO (2005):** *Plan for Managing Acute Air Pollution Episode,* Presentation by Greater Cairo Regional Branch Office (GCRBO) of the Egyptian Environmental Affairs Agency (EEAA) in the Air Pollution Inventory Workshop, Regionanal Environmental Management Improvement Project (REMIP), July 2006.


34. **Law No.4 Executive Regulations (2005):** The Executive Regulations Of The Law On Environment Promulgated By Law No. 4 Of The Year 1994 (As


It shall be absolutely prohibited to openly burn the garbage and non-dangerous solid wastes. Throwing or treating the garbage and solid wastes shall be prohibited except in the places appropriated for the purpose away from the dwelling, industrial, and agricultural areas, and from the water courses, according to the specifications, regulators, and minimum limit of their remoteness from these areas, as indicated in the following:

**First :**

The local government units shall appropriate places for receiving the garbage and solid wastes and for their treatment, following an integral study of the area’s topography and nature, and the quantity required to dispose of every 24 hours, according to the conditions and specifications indicated in annex (11) attached to the present regulations.

**Second :**

The concerned administrative entity, or the entity granting the license shall assess the environmental effect of the places and establishments for which a license is requested for their appropriation to receive and treat the garbage and solid wastes according to the elements, designs, specifications and bases to be issued by the Environment Affairs Agency in agreement with the concerned administrative entity, and to the environmental conditions and specifications prescribed in annex (11) attached to the present regulations. A copy of the assessment of the said environmental effect shall be sent to the Environmental Affairs Agency to express its view and recommend the proposals required for implementation in the field of the equipments and systems necessary for treating the negative environmental effects. The concerned administrative entity or the entity granting the license shall verify the implementation of these proposals.

**Third :**

Places of casting the garbage and solid wastes, and of their treatment establishments as well as the places of sanitary burying of wastes shall be located at a distance of 1500 meters away from the nearest dwelling area. The site of establishments for treating the farm and domestic animal wastes and the agricultural wastes shall be located at a distance of 500 meters away from the nearest dwelling area.

The remoteness of these places and establishments from the agricultural and industrial areas and the water courses shall be determined in light of studying the assessment of their environmental effect and the conditions prescribed in annex (11) attached to the present regulations.

These distances may, for necessity exigencies and in rural areas, be modified according to the conditions of the area or governorate, conditional upon the approval of the local entities, the Environmental Affairs Agency, and the concerned administrative entity or the entity granting the license.
Fourth:
The treatment of garbage and solid wastes shall be carried out according to the following systems:

1. Separating and re-using/retrieving/recycling some of their components “Paper – glass – plastic – metals, ……etc.”.
2. Biological treatment with the existence of or in isolation from air.
4. Thermal treatment with or without retrieval of energy.
5. Chemical treatment according the nature of wastes.

Using the method of cremation in special units observing the conditions prescribed in annex (11) attached to the present regulations may also be applied.
Annex 2
Technical Report for Emissions Measurements of Sharqia Biogasification Plant

Table 8: Indoor measurements by the gasification unit during operation

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONCENTRATION (MG/M³)</th>
<th>LIMITS OF LAW 4/1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>1.2</td>
<td>5</td>
</tr>
<tr>
<td>CO</td>
<td>4.5</td>
<td>55</td>
</tr>
<tr>
<td>NOₓ</td>
<td>0.9</td>
<td>6</td>
</tr>
</tbody>
</table>

(Source: EEAA technical report of gas measurements, 2005)

Table 9: Indoor measurements by the end-users stove during operation

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONCENTRATION (MG/M³)</th>
<th>LIMITS OF LAW 4/1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>0.8</td>
<td>5</td>
</tr>
<tr>
<td>CO</td>
<td>3.3</td>
<td>55</td>
</tr>
<tr>
<td>NOₓ</td>
<td>0.5</td>
<td>6</td>
</tr>
</tbody>
</table>

(Source: EEAA technical report of gas measurements, 2005)
Annex 3
Interviews with Manager and Ex-Manager of EEAA Gasification Pilot Plants

Date: April 11, 2007 (Interview 1) and May 3, 2007 (Interview 2)
Venue: 4th floor, EEAA (Interview 1) and 2nd floor, EEAA (Interview 2)
Subject: Gathering information about Biogas plants of EEAA
Interviewees:
1. Dr. Magdy Mahmoud Labib, Minister Advisor for Agricultural Affairs and Manager of the EEAA Biogas Pilot Plants Project
2. Dr. Essameldin Amer, Ex-Manager of the Biogas Pilot Plants Project
Interviewer: Ahmed El-Dorghamy

Notes:
Two gasification units for production of producer gas imported from China have been bought and operated by EEAA since 2003, with the objective of exploring alternative uses of rice straw, the raw material. They are located in Daqahlia and Sharqia governorates.

Both plants are similar, with the following data:

Design Capacity: 300 families, i.e. 300 x 2.33 m³/family.day = 700 m³/day
Production rate (Sharqia): 50 families, i.e. 117 m³/day
Production rate (Daqahlia): 57 families, i.e. 133 m³/day
Raw material: Rice Straw and Corn Cobs (ذرة ﻗﻮاﻟﺢ)
Product Gas: 10-12% CH₄, 1.8 m³ gas/kg straw
Main Wastes:
- Tar (from filters)
- Ash (spread as fertilizer)

Land Area (all facilities): 10500 m² (2.5 Feddan), however, 1-1.5 feddan can be sufficient and possibly less.
Labour: 16 persons (but only 4 were sufficient in earlier years)
EIA: No EIA has been conducted but emissions at the end user have been measured by the EEAA Central Labs (CCC), showing acceptable results.

Costs:
Equipment: 1.38 million LE (2 x 145000 USD -2003) provided by China for both plants, including civil works, installation, and a 3-month training program.

Contact info:
Name: Sharqia Biogas Plant (ﺑﺎﻟﺸﺮﻗﻴﺔ اﻟﻐﺎز إﺗﻨﺎج ﻣﺼﻨﻊ);
Address: Markaz Abu Hammad, Kafir El-Azzazy, Modiriyet El-Mahatta;

Description: Unit consists of a rice straw shredder, a screw feeder to the gasifier, a pump for pumping the gas to the gas holder (dipped in water) and a gas distribution system.
The offered prices of the producer gas is 22 piasters/m³. As a comparison, the prices for natural gas are:

First 30m³: 10 piasters
2nd 30m³: 20 piasters
3rd 30m³: 30 piasters

The price from the Gas Company: 15-17 piasters/m³. The biogas is cheaper than the Gas Company network gas.

The Egyptian Gas Company (Ministry of Petroleum) makes the gas network connection for 4300LE (previously 2000LE in the old contract), and runs maintenance.

Further information can be obtained from:
1. Layout design
2. Engineering design
3. Manual/Guidebook (for operation and security measures)

However, a letter signed by the CEO of EEAA is needed to obtain this information.

The current pending issue is the method to collect the gas bill; EEAA is discussing whether collection should be done by the Gas Company or the Governorate, or an investor. There are plans to hand the plants to the Ministry of Petroleum.

The main limitations to promote such projects are the availability of land area (it will naturally be agriculture land since it must be near to the raw material source), and the body that will operate and collect fees, and the difficulties in transporting the rice straw (truck capacity = 5-6 tons/truck, supplied in bales).

Currently there are plans to promote local production of the unit. The bodies discussing this issue with EEAA are:
1. Arab Production Agency (الهيئة العربية للتصنيع)
2. Military Production (الإنتاج العربي)
3. Ossman Ahmed Ossman
During the rest of the year, rice straw is delivered from storage, either in the plant storage, or from farmers. Therefore the price of rice straw is: 100 LE/ton during harvest, and 130 LE/ton out of season. So far, EEAA pays for the rice straw.

Delivery of rice straw is carried out mainly by Queen Service Company (transports 75000 tons annually) in addition to other local companies. Part is delivered in the winter period (since the straw stored in the open storage becomes wet) and in the summer, the stored straw dries and can be used.
Annex 4
Notes on Visit to the Biogasification Plant of Sharqia

Date: Saturday, May 11, 2007
Site Location: Sharqia Biogas Plant (مصنع إنتاج الغاز بالشرقية), Markaz Abu Hammad, Kafr El-Azzazy, Modiriyet El-Mahatta.

Plant Manager: Eng. Ahmed Mohamed Elewah.
Other staff: Tech. Mohamed El-Sayed (electrician) and plant operators.

Notes:
14. Plant located in a rural residential area, and occupying 2.5 acres of fertile land.
15. It delivers rice-straw derived biogas to nearby households as a pilot project.
16. The average demand is 275m³/day.
17. The personnel are a team of 16: 1 manager, 2 Agricultural engineers, 2 secretaries, 6 daily workers, and 5 technicians.
18. Straw is supplied in compressed bales (Dimensions: 0.4x0.6x1.2, 80Kg), by Queen Service Company. Currently, enough straw is stored on site for about 2 years.
19. Two storage locations for rice straw are in the site: one indoor (see fig. 2) and one outdoor, taking up about 1 acre.
20. Straw is manually fed into the Shredder. It operates at a rate of 1 ton/hr, shredding to a size of 2-10 cm.
21. The shredded straw is temporarily stored in a small room (about 3x3m)
22. A screw conveyor feeds the straw into a downdraught fixed grate gasifier. The gasification is continuously controlled manually through an open port. This is done in shifts of two hours to reduce stress on the worker monitoring the feeding.
23. In each charge, 1 – 1.3 tons of rice straw are fed.
24. The product gas enters into a series of flue gas cleaning/scrubbing stages enclosed in one unit:
   a. Cyclone for Ash removal.
   b. Bubbling water tank for dust separation and cooling (tar condensation)
   c. Corn stubs filter, followed by a water cooled indirect contact condenser for removal of remaining tar.
25. A minor part of the gas stream exiting the gas cleaning system is diverted to a test flame (a gas stove is also connected for demonstration and for staff use).
26. The product gas is pumped by a 5hp pump to charge gas tank.
27. The gas tank has a gas capacity of 350m³. The concept of the tank is to trap gas under a gas holder (inverted tank) floating on a partially filled water tank. The water volume in the tank is 500m³. The gas volume is monitored manually by checking the marks on the floating roof.
28. Product gas is then distributed through polypropylene pipes to households.
29. Wastes:
   a. Ash: Dumped in an outdoor ash pit, and manually sprayed with water to avoid fires.
   b. Tar: Most is discharged in an outdoor sink with the effluent water.
   c. Water:
      i. Direct-contact filter water (as in ‘b’): 1.5m³/month is changed.
ii. Check-valve water: 1 m3/month is changed.

d. Corn Stubs: manually removed.
e. Sanitary waste: 16 workers. Waste is used as fertilizer for the site’s grassland.

30. Emissions:
a. Fugitive product gas during feeding;
b. Test flame (indoors):

31. The main problem in operating the plant is the fluctuating demand, since low flow rate causes excessive tar depositing.

32. National Gas used to connect piping to the households, but now it is the Egyptian Gas Company, which is performing better.

33. Social Acceptance:
a. Recipients note that the flame is lower in temperature than with natural gas, therefore takes more time to cook food. However, the food tastes better for the same reason.
b. “Some noticeable smell during the first use, but gone afterwards” – Random user.
c. Some inconvenience has been experienced due to tar clogging on the users’ side.

34. It was noted during the interviews that tar deposits are sometimes cleaned using transformer oil. Such oils are known to contain potentially carcinogenic PCBs.